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**All Cumulative Semantic Interference is Not Equal:
A Test of the Dark Side Model of Lexical Access**

by

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ABSTRACT

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Language production depends upon the context in which words are named. Renaming previous items results in facilitation while naming pictures semantically related to previous items causes interference. A computational model (Oppenheim, Dell, & Schwartz, 2010) proposes that both facilitation and interference are the result of using naming events as “learning experiences” to ensure future accuracy. The model successfully simulates naming data from different semantic interference paradigms by implementing a learning mechanism that creates interference and a boosting mechanism that resolves interference. This study tested this model’s assumptions that semantic interference effects in naming are created by learning and resolved by boosting. Findings revealed no relationship between individual performance across semantic interference tasks, and measured learning and boosting abilities did not predict performance. These results suggest that learning and boosting mechanisms do not fully characterize the processes underlying semantic interference when naming.

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All cumulative semantic interference is not equal:

A test of the Dark Side Model of lexical access

Our ability to quickly and accurately produce speech depends on our prior language production experiences. For example, naming a picture that we named previously results in faster and more accurate naming, a phenomenon known as repetition priming (e.g., Cave, 1997; Durso & Johnson, 1979; Mitchell & Brown, 1988; Monsell et al., 1992). Repetition priming results from a speech production system that utilizes each naming event as a “learning experience” to ensure future efficiency and accuracy (e.g., Mitchell & Brown, 1988, Oppenheim, Dell, & Schwartz, 2010). However, all priming effects are not facilitatory in nature, as evidenced by the fact that naming pictures primed by semantically related items results in longer naming latencies and increased error rates. This semantic interference effect is thought to reflect the same long-lasting learning experience that facilitates naming (Oppenheim et al., 2010), as studies looking at semantic interference find this interference effect regardless of whether semantically related pictures are presented one after another (i.e., blocked-cyclic naming; e.g., Belke, Meyer, & Damian, 2005; Brown, 1981; Damian & Als, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994; Maess, Friederici, Damian, Meyer, & Levelt, 2002; Navarrete, Del Prato, & Mahon, 2012; Schnur, Schwartz, Beecher, & Hodgson, 2006) or are presented distantly, with anywhere from two to eight intervening semantically unrelated items (i.e., continuous naming; e.g., Howard, Nickels, Coltheart, & Cole-Virtue 2006; Runnqvist, Strijkers, Alario, & Costa, 2012; Navarrete, Mahon, & Caramazza, 2010). The aim of this study is to test the assumptions of a language production model that successfully simulates the data from these two semantic interference paradigms by

implementing both positive and negative effects of the “learning experience” when naming (i.e., Dark Side Model, Oppenheim et al., 2010; cf. Howard et al., 2006). Testing the assumptions of this model will garner a better understanding of the language production system, especially as it relates to the effects of facilitation and interference.

Oppenheim et al. (2010) propose a computational model of the language production system (henceforth, Dark Side Model) that accounts for both repetition priming and semantic interference effects by assuming two mechanisms underpin the processes by which we produce words. The first reflects the “learning experience”, implemented as a *learning mechanism* that operates over the connections between semantic features (e.g., *four legs, fur, tail*) corresponding to a target word (i.e., *dog*) and its word form, or lexical representation (“dog”). Repeating a word facilitates naming, as the semantic-to-lexical connections (hereafter, lexical-semantic connections) strengthen after naming an item. At the same time, the *learning mechanism* ensures that items sharing semantic features with the named target (e.g., *cat*) will not be strong competitors in the future by weakening the lexical-semantic connections they share with the named target. Consequently, it is difficult to name multiple semantically related items because of previous weakening of their lexical-semantic connections. In sum, the learning process both helps and hinders naming performance due to lexical-semantic connection weight changes.

In addition to the *learning mechanism*, the Dark Side Model (Oppenheim et al., 2010) implements a *boosting mechanism* proposed to help select the appropriate word from among other competitors sharing semantic features with the target word. Because learning weakens the connection weights of semantically related competitors, subsequent

naming of related items is difficult, and as such may require a control mechanism (Schnur et al., 2006, 2009). Therefore, Oppenheim et al. (2010) propose a *boosting mechanism* that can assist selection by heightening the activation levels of word candidates, enabling us to select a previously weakened word in the face of recently strengthened competitors. In doing so, this *booster* multiplies each word's activation level by a constant factor, until activation of a lexical item exceeds an absolute threshold. In this manner, response time is simulated as a function of the number of boosts required for a word to reach the threshold and thereby be selected. Accordingly items with weakened lexical-semantic connections require more boosts, leading to longer response times (i.e., semantic interference).

Using these two mechanisms of *learning* and *boosting*, the Dark Side Model (Oppenheim et al., 2010) successfully simulates data from two semantic interference tasks: blocked-cyclic naming (e.g., Damian & Als, 2005; Damian et al., 2001; Maess et al., 2002; Schnur et al., 2006) and continuous naming (e.g., Brown, 1981; Howard et al., 2006; Navarrete et al., 2010; Runnqvist et al., 2012). Each of these tasks manipulates the semantic relationship among target items in order to elicit semantic interference effects. Below, I describe these two tasks and how their semantic interference effects can be interpreted within the framework of this model.

Semantic Interference Tasks

Blocked-cyclic naming. The blocked-cyclic naming task elicits semantic interference by manipulating the context in which target items appear. Pictures appear either in semantically related (e.g., *cat*, *dog*, *bird*) or unrelated contexts (e.g., *cat*, *car*, *lamp*) called blocks, and are repeated for a number of times (cycles) in different orders

(e.g., Biegler, Crowther, & Martin, 2008; Damian & Als, 2005; Damian et al., 2001; Kroll & Stewart, 1994; Schnur et al., 2006). Semantically related, as compared to unrelated, contexts increase response latencies across the block, an effect I refer to as the *blocking effect* (see Figure 1).

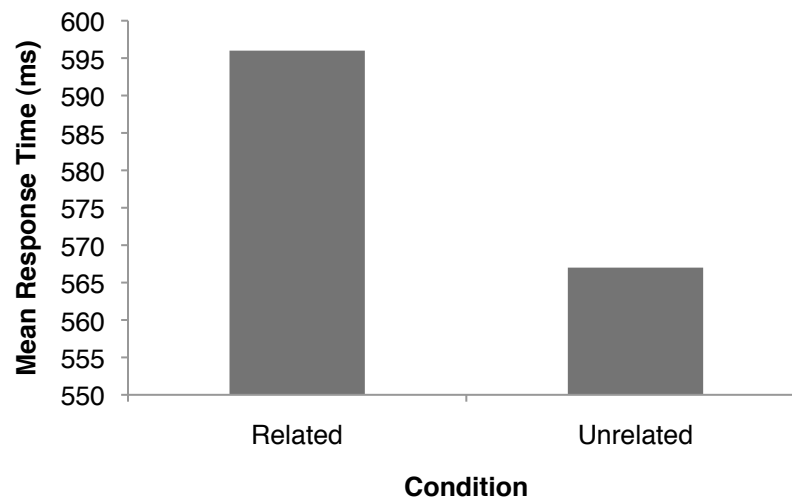


Figure 1. Response times collapsed across all cycles by related and unrelated conditions. Adapted from “Effects of Semantic Context in the Naming of Pictures and Words,” by M. F. Damian, G. Vigliocco, and W. J. M. Levelt, 2001, *Cognition*, 81, p. B80. Copyright 2001 Elsevier Science B.V. Adapted with permission.

Repeating items allows for examining interference as it emerges with repetition (across cycles). As shown in Figure 2, the difference in response latencies (Related - Unrelated Conditions) increases across cycles, an effect I will refer to as the *growth effect*.

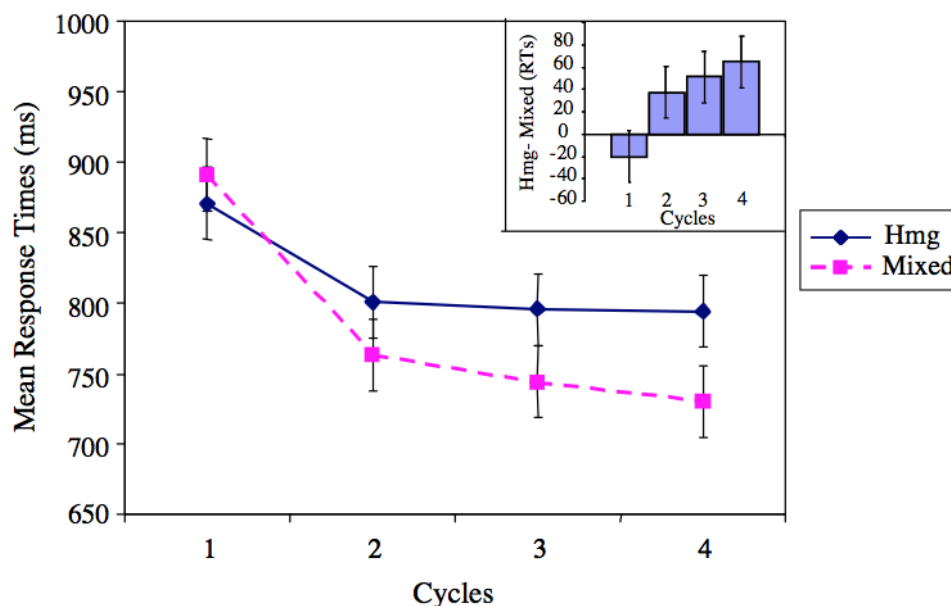


Figure 2. Response times across four naming cycles in both the Related (HMG) and Unrelated (Mixed) conditions. The bar graph in the upper right corner illustrates the interference effect (Related - Unrelated) as it increases across the four cycles. Reprinted from “Semantic interference during blocked-cyclic naming: Evidence from aphasia,” by T. T. Schnur, M.F. Schwartz, A. Brecher, C. Hodgson, 2006, *Journal of Memory and Language*, 54, p. 210. Copyright 2005 Elsevier Inc. Reprinted with permission.

Both the *blocking* and *growth effects* in blocked-cyclic naming occur due to the *learning mechanism* strengthening and weakening lexical-semantic connections of previously named and unnamed same-category items, and the time the *boosting mechanism* needs to assist selection of previously weakened items. Overall, performance improves when repeating items (i.e., repetition priming), but this benefit is attenuated in the semantic context due to the weakening of connections. Thus, the model proposed by Oppenheim et al. (2010) accounts for both repetition priming and interference effects that occur in this paradigm.

Continuous naming. In the continuous naming paradigm (e.g., Brown, 1981; Howard et al., 2006; Navarrete et al., 2010; Runnqvist et al., 2012), pictures are drawn in groups from different semantic categories and are then named one-by-one with no two pictures in a row from the same category (e.g., BIRDS: *swan*, *owl*, *eagle*, *duck*, *parrot*).

In contrast to the blocked-cyclic naming paradigm, each picture is named only once, and the position of a picture within its category members is called its ordinal position. As each exemplar from a category is named, naming times increase across ordinal positions, and this increase is linear in nature (e.g., Howard et al., 2006). I will call this effect the *ordinal slope*. Importantly, the number of unrelated items appearing between related stimuli does not affect the increased response latencies across ordinal positions (Howard et al., 2006; Navarrete et al., 2010), as shown in Figure 3.

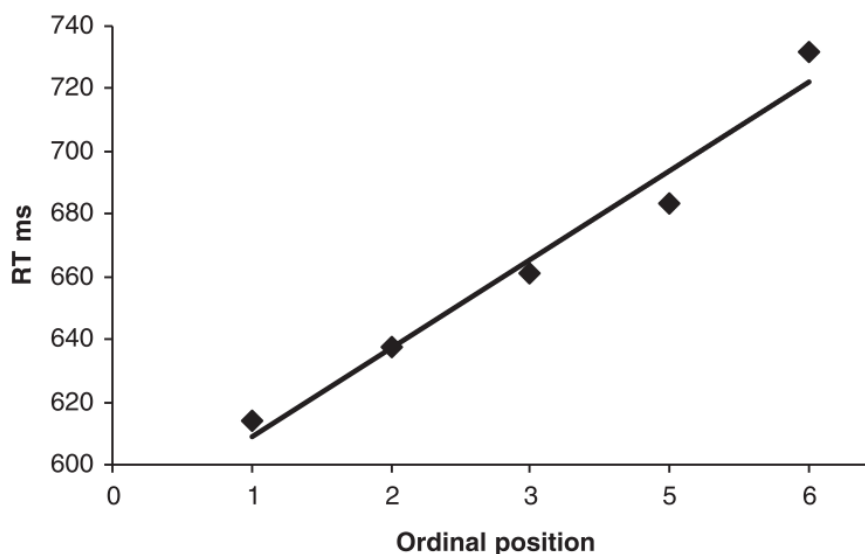


Figure 3. Response times across five ordinal positions, collapsed across the number of intervening unrelated trials appearing between related stimuli. Reprinted from “Cumulative semantic interference in picture naming: experimental and computational studies,” by D. Howard, L. Nickels, M. Coltheart, and J. Cole-Virtue, 2006, *Cognition*, 100, p. 469. Copyright 2005 Elsevier B. V. Reprinted with permission.

Once again, Oppenheim et al.’s (2010) model accounts for this *ordinal slope effect*, as *learning* strengthens target lexical-semantic connections after naming while concurrently weakening those of items semantically related to the target. Therefore, naming latencies increase with each additional category item due to previous weakening of that item, resulting in the linear *ordinal slope* pattern that this paradigm produces (Howard et al., 2006; Navarrete et al., 2010; Runnqvist et al., 2012).

In assuming that performance on naming these tasks is driven by *learning* and *boosting mechanisms*, this model generates predictions about an individual's performance across these tasks. Specifically, an individual's strength in *learning* and *boosting* should predict his/her task performance. To test the predictions of this model, my study tested the following assumptions of the Dark Side Model (Oppenheim et al., 2010).

1. The semantic interference effects observed in blocked-cyclic and continuous naming are the same effect.
2. The *learning mechanism* creates semantic interference in blocked-cyclic and continuous naming.
3. The *boosting mechanism* facilitates the resolution of semantic interference in blocked-cyclic and continuous naming.

This model predicts that an individual's performance in blocked-cyclic naming correlates with that of continuous naming. Although this seems intuitive, as they are both manifestations of semantic interference, to my knowledge, performance in these tasks has not been compared. Previous research demonstrates that individuals vary in their susceptibility to semantic interference (Maess et al., 2002), and this model predicts that the magnitude of interference in these paradigms should be correlated. As there are distinct differences in the way each task elicits semantic interference (e.g., organization of related items, repetition of items), it remains unclear whether the interference effects observed in block-cyclic naming are the same as those in continuous naming. My study presents a comparison of these tasks by directly comparing interference effects within individuals across tasks. Furthermore, as individuals vary in their *learning* and *boosting* abilities (e.g., Woltz & Schute, 1993), if the *learning* and *boosting mechanisms* underlie

the interference effects observed in these two tasks, then individual strength in these mechanisms should predict task performance. Therefore, I tested individual differences in *learning* and *boosting mechanism* strength to determine if these two proposed mechanisms predict semantic interference effects.

Learning Mechanism

In order to assess whether an individual's *learning mechanism* strength predicts his/her susceptibility to semantic interference, I examined individual performance on a repetition priming task. As previously mentioned, repetition priming refers to a facilitatory effect, where naming the same picture results in faster and more accurate naming the second time (e.g., Cave, 1997; Durso & Johnson, 1979; Mitchell & Brown, 1988; Monsell et al., 1992). Critically, repetition priming lasts over long delays of up to 50 items (Durso & Johnson, 1979) and persists even with separations of up to 48 weeks between the first and second naming trials (Cave, 1997)¹. This is consistent with findings from continuous naming and the model proposed by Oppenheim et al. (2010) such that the semantic interference effect is long-lasting. In this case, any task that utilizes repeated picture naming in the absence of manipulating the semantic context of target items (i.e., repetition priming task) isolates the *learning mechanism* from the *boosting mechanism*. In a repetition priming task, items are split into two groups: old items (repeated), and new items (not repeated). According to the Dark Side Model, the difference between these two conditions (old, new) is a measure of the amount of *learning* that is occurring in the lexical-semantic connections (Oppenheim et al., 2010). Therefore, an individual's

¹ In both cases, although the repetition priming effect is still significant, there is some diminution in this effect at long compared to short delays (intervening items or time) (e.g., Cave, 1997; Durso & Johnson, 1979).

learning strength should predict the amount of interference that he/she exhibits in blocked-cyclic naming and continuous naming. In this regard, *learning* strength should correlate with the *blocking effect* and the *growth effect* in blocked-cyclic naming and the *ordinal slope* in continuous naming. Critically, based upon the structure of the Dark Side Model, the ability to strengthen connections via *learning* (resulting in repetition priming) is a measure of both the strengthening and weakening functions of the *learning mechanism*, as the same parameter is used to simulate both of these processes.

Boosting Mechanism

The *boosting mechanism* helps to direct selection when the target is difficult to distinguish from competitors (Dell, Oppenheim, & Kittredge, 2008; Kan & Thompson-Schill, 2004; Oppenheim et al., 2010; Schnur et al., 2006, 2009). Support for the *boosting mechanism* as fundamental to the resolution of semantic interference comes from studies using the blocked-cyclic naming paradigm to investigate the neuroanatomical basis of the semantic interference effect. Based on previous research demonstrating that the left inferior frontal gyrus (LIFG) is critical in supporting selection from competition (e.g., Kan & Thompson-Schill, 2004; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997), Oppenheim et al. (2010) suggest this region may be the neuroanatomical substrate of their *boosting mechanism*. Consistent with their prediction, both Pisoni, Papagno, and Cattaneo (2012) and Schnur et al. (2009) examined the neural underpinnings giving rise to semantic interference during the blocked-cyclic naming task and found that the activity in the LIFG related to one's ability to resolve interference. Additionally, the LIFG also responds to task manipulations that do not involve the *learning* process (e.g., Kan & Thompson-Schill, 2004). For example, naming pictures that vary in the number of

permissible names (high vs. low name agreement (NA)) isolates competition from *learning*. In a high/low NA task, selection demand is manipulated by having subjects name stimuli with one dominant name (high NA; e.g., *apple*) and stimuli with more than one permissible name (low NA; e.g., *sofa/couch*) (e.g., Alario et al., 2004; Hartsuiker & Notebaert, 2010; Kan & Thompson-Schill, 2004; Thompson-Schill et al., 1998; Vitkovitch & Tyrell, 1995). High NA constitutes a low selection condition, as there is only one dominant name, while low NA constitutes a high selection condition, as there are multiple possible answers. High selection demand stimuli slow response latencies for normal subjects and elicit greater LIFG activation (Kan & Thompson-Schill, 2004), and the difference between the high selection condition and the low selection condition is a measure of the strength of the *boosting mechanism*, as high selection demand stimuli require more boosts to reach the selection threshold. As such, the difference between these two conditions (high selection (low NA) vs. low selection (high NA)) measures an individual's ability to utilize the *boosting mechanism* in order to select an item from competitors (Oppenheim et al., 2010). Therefore, the ability to resolve competition in this task (i.e., *boosting mechanism* strength) should predict the resolution of interference in blocked-cyclic and continuous naming.

In this study, I used four experimental paradigms with the same subjects to test the assumptions of the Dark Side Model (Oppenheim et al., 2010). First, I used the two semantic interference paradigms that it simulates: blocked-cyclic naming (Experiment 1) and continuous naming (Experiment 2). I then used two paradigms that tap into the mechanisms of this model. I tested the *learning mechanism* using a repetition priming task (Experiment 3) and the *boosting mechanism* using a high/low name agreement

picture naming task (Experiment 4). Taking individual results from each of these experiments, I calculated the magnitude of semantic interference exhibited by each individual in blocked-cyclic and continuous naming paradigms and assessed performance on the tests of the *learning* and *boosting mechanisms*. I then performed correlation analyses to determine if variability in semantic interference effects observed across individuals is correlated and if the mechanism measures account for performance in these tasks.

To anticipate my findings, I replicate previous effects of semantic interference in blocked-cyclic naming (e.g., Belke et al., 2005; Damian & Als, 2005; Damian et al., 2001; Maess et al., 2002; Navarrete et al., 2012; Schnur et al., 2006) and continuous naming (e.g., Howard et al., 2006; Runnqvist et al., 2012; Navarrete et al., 2010). I provide evidence that repetition priming facilitates naming as predicted by a *learning mechanism* (replicating Cave, 1997; Durso & Johnson, 1979; Mitchell & Brown, 1988; Monsell et al., 1992) and low name agreement words create greater selection demands, requiring the *boosting mechanism* (replicating Alario et al., 2004; Hartsuiker & Notebaert, 2010; Kan & Thompson-Schill, 2004; Thompson-Schill et al., 1998; Vitkovitch & Tyrell, 1995). However, correlation analyses assessing the relationship between semantic interferences effects and *learning* and *boosting mechanisms* were not significant, suggesting that all semantic interference is not equal and the mechanisms responsible for interference may lie outside the scope of Oppenheim et al.'s (2010) model. In the General Discussion, I explore potential reasons as to these findings as well as how the Dark Side Model might be modified to support these results.

Experiment 1

Experiment 1 had two aims. The first was to replicate previous semantic interference effects in blocked-cyclic naming that response times (RTs) are longer when naming stimuli in semantically related groups than when naming stimuli in unrelated groups (*blocking effect*) (e.g., Belke et al., 2005; Damian et al., 2001; Schnur et al., 2006), and that this semantic interference effect grows across each cycle (*growth effect*) (e.g., Schnur et al., 2006; Schnur et al., 2009). The second was to obtain individual measures of these interference effects for each subject.

Methods

Unless otherwise noted, methods are the same across all experiments.

Participants. Participants were 36 students attending Rice University. All participants were native English speakers with normal or corrected to normal vision. I removed two participants from further analyses as a result of failures of the voice-key to trigger. Participants were assigned research credit for participating in the experiment or were monetarily compensated. All participants gave informed consent in accordance with Rice University's Institutional Review Board and were debriefed after the experiment. All participants completed the four experiments presented in this study in one session. The order in which they completed these experiments varied across participants using a Latin square design.

Materials. Stimuli were photographs taken from the Bank of Standardized Stimuli (BOSS) (Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010), the standardized set of ecological pictures (Viggiano, Vannucci, & Righi, 2004), the real world normed picture set (Karst, Clapham, & Wessinger, 2009) and online google.com image search.

No stimulus was used in more than one experiment. Stimuli were 60 photographs, consisting of 12 semantic categories of 5 exemplars each (e.g., furniture: table, desk, bed, chair, stool) (see Appendix A). In the semantically related condition, all 5 exemplars (comprising one cycle) in a semantic category were presented 5 times each in that block (for a total of 5 cycles), in a randomized presentation, alternating with the other semantically related exemplars. I ensured that the final item of a cycle did not appear as the first item of the next naming cycle and that no two items with the same phonological onset appeared in a row. Semantically related blocks comprised a total of 300 trials (12 blocks x 5 stimuli x 5 presentations). In the semantically unrelated condition, all five images were randomly chosen from the 60 total images with the requirement that they come from five different semantic categories (e.g., cup, desk, paintbrush, goat, apple). These five images were presented for five cycles in each block, alternating with the other semantically unrelated images, with the same randomization and requirements for order as were used in the semantically related blocks. Unrelated blocks consisted of 300 trials.

The presentation order of semantically related and unrelated blocks was random with the requirement that no more than two blocks of the same condition were presented successively. There were two different trial orders of the experiment, where the only difference between the two was the order in which the blocks appeared. Half of the participants completed one order, while the other half completed the other.

Apparatus. Photographs were presented one-at-a-time on a PC using DMDX (Forster & Forster, 2003). Participants named the exemplars using a microphone headset that recorded their responses and RTs to the nearest millisecond. The experimenter also recorded participant responses.

Procedure. Following Schnur et al. (2006), before the experiment began, I familiarized participants with the photographs, presenting all photographs once in a random order where participants named each exemplar and then were presented with corrective feedback. This was a total of 60 trials for the 60 stimuli. The experiment began with instructions to name all presented photographs as fast and as accurately as possible. Participants pressed the space bar to begin the experiment. On each trial, a fixation cross “+” appeared for 1000 ms, then the photograph appeared. The response deadline was 1600 ms. After each block, a screen appeared telling the subject to prepare for the next block. Subjects pressed the spacebar in order to advance to the next block.

The experiment was run once per participant. Each exemplar was presented ten times in total, five times in a semantically related block and five times in an unrelated block. In total, participants were tested on 600 trials.

Results & Discussion

Group Analysis. The following types of responses were removed from the RT analyses: omissions (<1%), microphone errors (1.9%), voice key errors (coughing, sneezing, etc.) (<1%), and naming errors (<1%). Errors accounted for 2.9% of the data. Due to the low number of omission and naming error responses, no error analyses were conducted. RTs faster than 250 ms were excluded from analysis as well as RTs outside of three standard deviations from each subject’s mean RT.

I conducted two types of ANOVAs using RTs as the dependent variable in which either subjects (F1) or items (F2) was used as a random factor. Figure 4 displays the RTs in each condition across the 5 cycles. The results displayed a significant effect of semantic context (21 ms) as subjects were slower to name items in the semantically

related condition (614 ms) as compared to the unrelated condition (593 ms) demonstrating a *blocking effect* ($F(1,33) = 116.50, p < .001$; $F(1,60) = 57.4, p < .001$). There was a significant effect of cycle ($F(4,132) = 28.90, p < .001$; $F(4,240) = 47.3, p < .001$), as subjects demonstrated repetition priming effects by responding more quickly across each presentation cycle. There was also a significant interaction between Condition and Cycle ($F(4,132) = 20.61, p < .001$; $F(4,240) = 18.47, p < .001$), as the difference between semantically related and unrelated RTs increased across naming cycles demonstrating a semantic interference *growth effect*. Figure 5 displays the *growth effect* across the cycles as shown by an increasing difference between the two conditions.

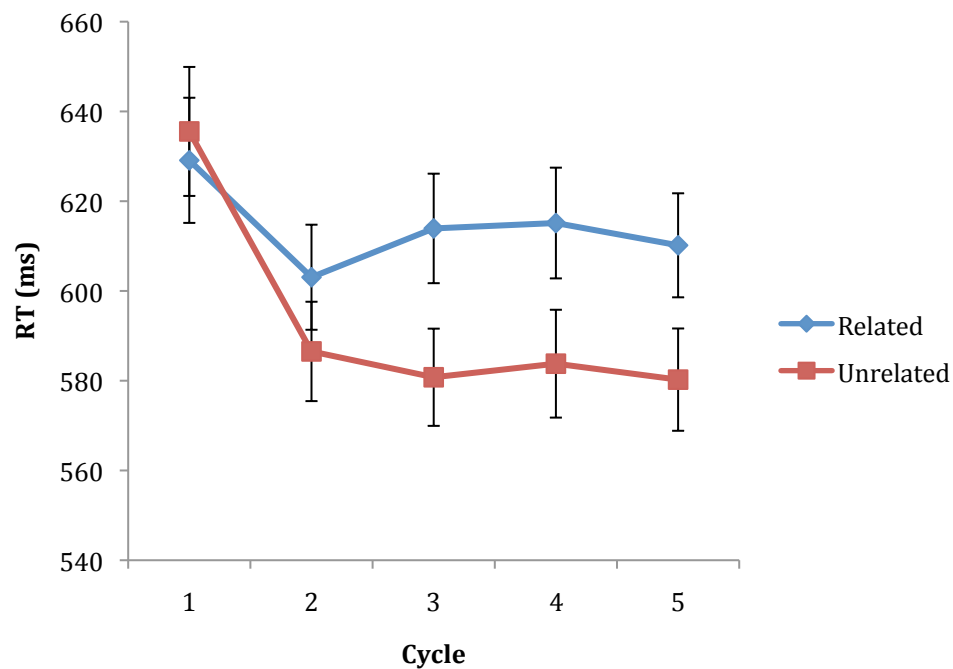


Figure 4. Experiment 1 mean RTs (ms) by condition (Related, Unrelated) and presentation cycle (1-5). Error bars represent one standard error from the mean.

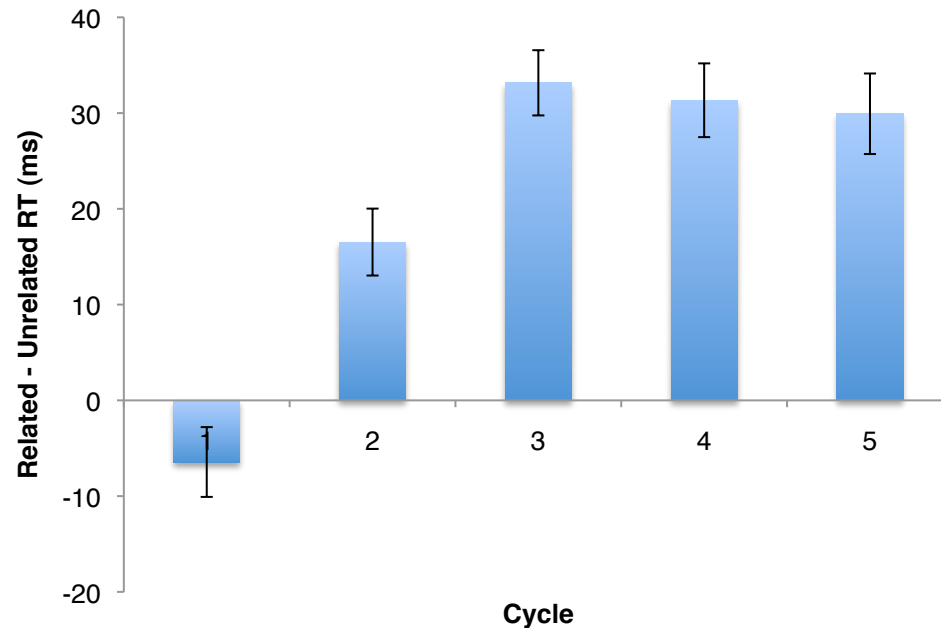


Figure 5. Experiment 1 mean RT difference (Related - Unrelated) by presentation cycle (1-5). Error bars represent within-subject 95% confidence intervals.

Individual Analysis. For each subject, I calculated the magnitude of his/ her semantic interference effects. These included the *blocking effect* and the *growth effect*, and were calculated as follows:

1. *Blocking Effect*: RT (ms) difference between conditions (Related – Unrelated)
2. *Growth Effect*: The slope of the RT (ms) difference between conditions (Related – Unrelated) across all five cycles of naming.

Subjects demonstrated variability in both of these measures. I checked each measure to ensure there were no outliers (i.e., outside of three interquartile ranges) and detected no outliers. Table 1 presents descriptive statistics for each semantic interference effect.

Table 1.

Descriptive statistics for the blocking effect and the growth effect.

Variable	Mean	SD	Minimum	¼ Quartile	Median	¾ Quartile	Maximum
Blocking Effect	21.41	11.32	-0.12	11.06	21.78	28.56	44.84
Growth Effect	8.75	7.35	-8.84	3.88	9.25	14.73	22.38

In order to determine the internal reliability of the *blocking* and *growth effects*, I performed a split-half reliability test (i.e. Spearman Brown formula, Allen & Yen, 1979) on each semantic interference effect by breaking each participant's trials into odd and even groups. I then calculated for each participant the previously described effects using each of these halves and calculated the correlation between these two halves as given by the Spearman Brown formula. I found split-half reliability for the *blocking effect* was $r = .79$ and for the *growth effect* was $r = .59$.

In Experiment 1, I replicated the semantic interference effect in blocked-cyclic naming (e.g., Belke et al., 2005; Damian et al., 2001; Schnur et al., 2006). I found that subjects were slower to name items grouped by semantic category than when they are in unrelated groups (*blocking effect*) and that this difference between semantically related and unrelated groups grows across multiple naming cycles (*growth effect*) (e.g., Navarrete et al., 2012; Schnur et al., 2006, 2009). While both the semantically related and unrelated blocks did show a general decrease in naming latencies across all five cycles (repetition priming), this decrease was more pronounced in the unrelated blocks than the semantically related blocks, providing evidence that repeatedly accessing items

from the same category attenuates this facilitatory effect, causing increasing interference to occur during the naming process.

Experiment 2

Experiment 2 had two aims. The first was to replicate previous effects in continuous naming that RTs are longer when naming an image from a semantic category after having previously named images from that category (e.g., Howard et al., 2006; Navarrete et al., 2010; Runnqvist et al., 2012) and that this increase in RTs across multiple category exemplars is linear (*ordinal slope*). The second was to obtain individual measures of this interference effect for each subject.

Methods

Materials. Stimuli were 60 color photographs, drawn from 12 semantic categories (different from Experiment 1), with five from each category (see Appendix B). Experiment 2 was run once per participant, with each photograph presented only once, for a total of 60 trials.

Procedure. The procedure is similar to that of Howard et al. (2006) with the following exceptions. Following Runnqvist et al. (2012), the number of pictures between items from the same category (lag) was kept consistent (lag of 2). Additionally, 12 semantic categories were used instead of 24 to prevent overlap of categories between Experiments 1 and 2. Each participant was given a different randomized order of exemplars and categories throughout the experiment, and these orders controlled for category order and randomized stimuli order across participants and were determined by a program written in MATLAB version 7.10.0. (The MathWorks Inc., 2010) (Schnur, submitted). The order of categories and stimuli was such that every third photograph was

drawn from the same category (lag 2) (e.g., category 1, category 2, category 3, category 1, category 2, category 3, etc.).

In contrast to Experiment 1, participants were not familiarized with the images in advance, and all trials were presented without breaks (following Howard et al., 2006).

Results & Discussion

Group Analysis. Following Howard et al. (2006), the following types of responses were removed from analysis: omissions (1.7%), microphone errors (2.7%), voice key errors (coughing, sneezing, etc.) (<1%), and naming errors (7.9%). These accounted for 12.4% of the data and were not included in analyzing the RT results. RTs were included in analysis based on the same criteria as in Experiment 1. I conducted two types of ANOVAs using RTs or errors as the dependent variable in which either subjects (F1) or categories (F2) (following Howard et al., 2006) was used as a random factor.

Table 2 presents RTs, standard error and confidence intervals for all five ordinal positions.

Table 2.

Experiment 2 means, standard error and 95% confidence intervals for each ordinal position.

Ordinal	Mean	Std Error	Lower 95%	Upper 95%
1	803.843	12.857	778.63	829.06
2	853.306	12.364	829.06	877.56
3	847.439	12.504	822.91	871.96
4	866.271	12.451	841.85	890.69
5	877.515	12.819	852.37	902.66

There was a significant effect of ordinal position ($F(4,132) = 6.01, p < .001$; $F(4,44) = 5.54, p = .001$). Specifically, subjects were increasingly slower to name from a category, and this effect was linear in nature (*ordinal slope*), characterized by a linear

contrast ($F(1,33) = 17.15, p < .001$; $F(1,11) = 12.90, p < .001$). Neither the quadratic (p 's $> .2$) nor the cubic contrasts (p 's $> .2$) reached significance. The error rate analysis across subjects and categories (a total of 196 omissions and naming errors) showed no significant effects (all p 's $> .22$).

Figure 6 displays RTs across the 5 ordinal positions. I calculated the *ordinal slope* by averaging RTs at each ordinal position and calculating the slope across all five positions. A best-fit line gave the slope of the effect ($r = .91, b = 16.4$ ms) indicating that on average subjects responded approximately 16 ms slower across each ordinal position.

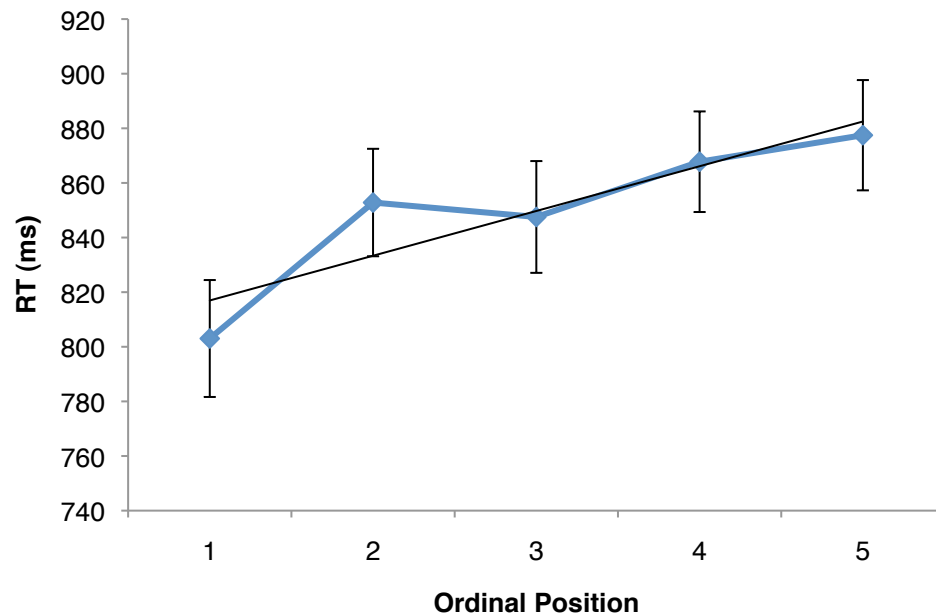


Figure 6. Experiment 2 mean RTs (ms) by ordinal position. Error bars represent one standard error from the mean.

Individual Analysis. For each subject, I calculated the magnitude of his/ her *ordinal slope* effect based on the increase of RTs for semantically related items across all five ordinal positions. Subjects demonstrated variability in this measure, and I found no outliers using the same criterion as in Experiment 1. Table 3 presents descriptive statistics for the *ordinal slope* effect. Split-half reliability for this effect was $r = .54$.

Table 3.

Descriptive statistics for the ordinal slope.

Variable	Mean	SD	Minimum	¼ Quartile	Median	¾ Quartile	Maximum
Ordinal Slope	15.88	23.21	-27.77	-4.23	17.15	30.31	69.56

In Experiment 2, I replicated previous results concerning the semantic interference effect in continuous naming (e.g., Howard et al., 2006; Navarrete et al., 2010; Runnqvist et al., 2012). Subjects became increasingly slower as they named multiple items from the same semantic category, even with intervening unrelated items, and as in previous results, I found this increase in RTs was characterized by a linear increase (*ordinal slope*). This semantic interference effect once again provides evidence that repeatedly accessing items from the same category causes increasing interference to occur in the naming process.

Experiment 3

Experiment 3 had two aims. The first was to replicate previous facilitatory effects in repetition priming that RTs are shorter when naming previously presented stimuli than when naming novel stimuli (e.g., Cave, 1997; Durso & Johnson, 1979; Mitchell & Brown, 1988; Monsell et al., 1992). This effect reflects the *learning mechanism* as proposed in the Dark Side Model (Oppenheim et al., 2010). The second aim was to obtain individual measures of this facilitatory effect for each individual to quantify his/her *learning mechanism* strength.

Methods

Materials. Stimuli were 90 photographs, and care was taken to minimize semantic relationships between stimuli (see Appendix C). The experiment was run once per participant, with two short picture naming sessions: old and new items (i.e., encoding and testing phases, respectively). During the encoding phase, participants named 60 images. After a brief pause, participants began the testing phase, in which they named 30 images from the first session (old items) and 30 novel images (new items). Participants were tested on a total of 120 trials comprising 90 different images.

There were two trial orders of each test session, so overall there were four versions of the experiment. Participants were randomly assigned to an experimental version with the requirement that each order be presented an equal number of times across all participants. In each trial order, exemplars were presented in a random fashion, with the requirement that no two photographs in a row shared phonological onset (e.g., *cat* and *car*) or semantic category.

Procedure. All 60 trials in the encoding phase were presented without breaks. There was a short pause between the two sessions, and then all 60 trials in the testing phase were presented without breaks.

Results & Discussion

Group Analysis. Following Mitchell and Brown (1988), only responses from the testing phase were used in the analyses, as this phase incorporates both primed and unprimed items. The following types of responses were removed from the RT analysis: omissions (2.1%), microphone errors (4.0%), voice key errors (coughing, sneezing, etc.) (<1%), and naming errors (5.2%). These accounted for 11.6% of the data. RTs were

included in the analysis based on the same criteria as in Experiment 1. Two of the new items used in the testing phase were removed due to high error rates (>50%).

I conducted two types of *t*-tests with RTs or errors as a random factor using paired *t*-tests across subjects (*t*₁) and unpaired *t*-tests across items (*t*₂). As a group, subjects were faster to name old items (763 ms) than to name new items (917 ms), a 154 ms significant repetition priming effect ($t_1(33) = 11.94, p < .001$; $t_2(56) = 6.87, p < .001$) displayed in Figure 7. Subjects demonstrated a repetition priming effect in errors as well, showing fewer errors (a total of 144 omissions and naming errors) in the old (2.2%) vs. new condition (5.1%) ($t_1(33) = 4.48, p < .001$; $t_2(56) = 2.06, p = .044$).

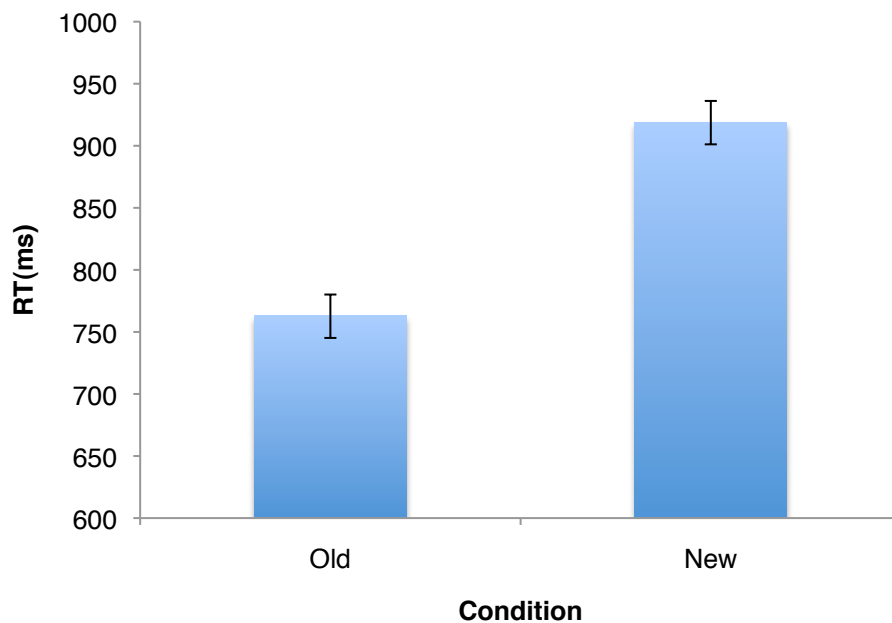


Figure 7. Experiment 3 mean RTs (ms) by condition (Old, New). Error bars represent one standard error from the mean.

Individual Analysis. For each subject, I calculated his/ her specific repetition priming effect, as this is a manifestation of the *learning mechanism* strength (Oppenheim et al., 2010). The *learning mechanism* was quantified as the RT (ms) difference between the two conditions (Old, New). Subjects demonstrated variability in this measure, and I

found no outliers using the same criterion as in Experiment 1. Table 4 presents descriptive statistics for this mechanism. Split-half reliability for this effect was $r = .75$.

Table 4.

Descriptive statistics for the learning mechanism.

Variable	Mean	SD	Minimum	¼ Quartile	Median	¾ Quartile	Maximum
Learning Mechanism	150.10	73.31	-51.40	104.02	158.03	216.65	312.17

In Experiment 3, I replicated previous effects in repetition priming (e.g., Cave, 1997; Durso & Johnson, 1979; Mitchell & Brown, 1988; Monsell et al., 1992), finding that old items are named more quickly than new items. That previously naming a particular exemplar facilitates naming that item in the future provides evidence supporting the existence of a *learning mechanism* that ensures faster and more accurate production in the future.

Experiment 4

Experiment 4 had two aims. The first was to replicate previous interference effects in high/low name agreement (NA) that RTs are longer when naming items with low NA (high selection demand) as compared to items with high NA (low selection demand) (e.g., Alario et al., 2004; Hartsuiker & Notebaert, 2010; Kan & Thompson-Schill, 2004; Thompson-Schill et al., 1998; Vitkovitch & Tyrell, 1995). As the increased lexical competition in the low NA condition necessitates the assistance of the *boosting mechanism* (Kan & Thompson-Schill, 2004), this interference effect is translated as the efficiency of the *boosting mechanism* in assisting selection. The second aim was to obtain

individual measures of this interference effect for each individual to quantify his/her *boosting mechanism* strength.

Methods

Materials. Stimuli were 54 photographs that fell either into a high NA category (27 items) or a low NA category (27 items) with name agreement taken from published norms (Brodeur et al., 2010) (see Appendix D). I used only items for which low NA was a result of that item having multiple permissible names. I did not use items that had low NA as a result of visual complexity or the use of abbreviated names. Name agreement for items in the high NA condition (mean 98%; range 87%-100%) significantly differed from those in the low NA condition (mean 74%; range 39%-86%) ($t(52) = 12.36, p < .001$).

Procedure. All participants were presented with the same photographs in the same trial order. The order of the trials was random, with the requirement that no two photographs in a row shared phonological onset or semantic category. All 54 trials were presented without breaks. The experiment was run once per participant, with each exemplar presented only once for a total of 54 trials.

Results & Discussion

Group Analysis. The following types of responses were removed from analysis: omissions (2.0%), microphone errors (4.2%) voice key errors (coughing, sneezing, etc.) (<1%), and naming errors (4.4%). These accounted for 10.6% of the data. RTs were included in the analysis based on the same criteria as in Experiment 1. One item in the high NA condition was removed due to visual confusability.

I conducted two types of t -tests with RTs or errors as a random factor using paired t -tests across subjects (t_1) and unpaired t -tests across items (t_2). Confirming NA norms

produced by Brodeur et al. (2011) subjects produced higher NA for items in the high NA condition (98.6%) than for items in the low NA condition (90.2%) ($t1(33) = 11.4, p < .001$; $t2(52) = 2.67, p = .011$). Further, subjects responded faster to high NA items (818 ms) than to low NA items (874 ms) ($t1(33) = 4.99, p < .001$; $t2(51) = 2.16, p = .036$) (see Figure 8). The error rate analysis (a total of 115 omissions and naming errors) showed a marginally significant effect of NA, $t1(33) = 2.12, p = .04$; $t2(51) < 1$.

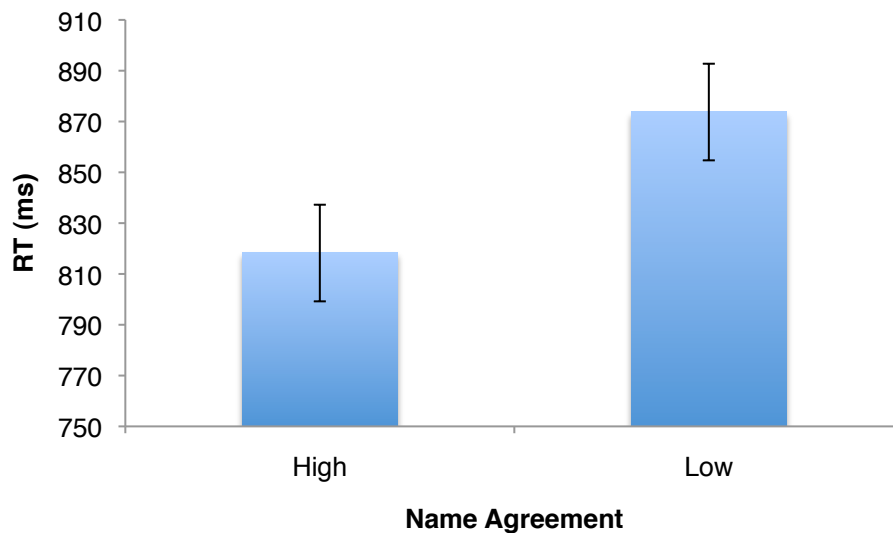


Figure 8. Experiment 4 mean RTs (ms) by condition (High NA, Low NA). Error bars represent one standard error from the mean.

Individual Analysis. I calculated each individual's *boosting mechanism* as quantified by the RT (ms) difference between the two conditions (High NA, Low NA) hypothesized to represent an individual's ability to resolve interference from competition (Kan & Thompson-Schill, 2004), to examine the efficiency of a mechanism critical for picture naming in situations of competition (Oppenheim et al., 2010). Subjects demonstrated variability in this measure, and I detected no outliers using the same criterion as in Experiment 1. Table 5 presents descriptive statistics for this mechanism. Split-half reliability for this effect was $r = .46$.

Table 5.

Descriptive statistics for the boosting mechanism.

Variable	Mean	SD	Minimum	¼ Quartile	Median	¾ Quartile	Maximum
Boosting Mechanism	55.50	64.81	-123.59	13.63	66.86	103.16	189.04

To summarize, I replicated previous effects demonstrating that subjects respond more slowly when naming items with multiple permissible names (low NA) compared to those with one dominant name (high NA) (e.g., Alario et al., 2004; Hartsuiker & Notebaert, 2010; Kan & Thompson-Schill, 2004; Thompson-Schill et al., 1998; Vitkovitch & Tyrell, 1995). That low NA items are named more slowly than high NA items is hypothesized to reflect a *boosting mechanism* required to assist with naming under conditions of increased competition (e.g., Kan & Thompson-Schill, 2004; Oppenheim et al., 2010).

Correlation Analyses

For each subject, I used his/her three semantic interference effects (*blocking effect, growth effect, ordinal slope*) and his/her two mechanism effects (*learning mechanism, boosting mechanism*) to test the following predictions that follow from assumptions in the Dark Side Model (Oppenheim et al., 2010):

1. The semantic interference effects observed in blocked-cyclic and continuous naming are produced by the same mechanism, generating the prediction that the *blocking effect* and/or the *growth effect* should correlate with the *ordinal slope*.

2. The *learning mechanism* creates semantic interference in blocked-cyclic and continuous naming, generating the prediction that the *learning mechanism* should correlate with the *blocking effect* and/or the *growth effect* and the *ordinal slope*.
3. The *boosting mechanism* facilitates the resolution of semantic interference in blocked-cyclic and continuous naming, generating the prediction that the *boosting mechanism* should correlate with the *blocking effect* and/or the *growth effect* and the *ordinal slope*.

For each presented correlation, I checked for outliers on the variables under consideration using Mahalanobis distances and considered any point to be an outlier whose Mahalanobis distance was greater than 13.82 (Meyers, Garnst, & Guarnio, 2006). I found no outliers in any of these measures.

I first examined the hypothesis that semantic interference in naming arises via a similar mechanism in both blocked-cyclic and continuous naming, by testing the subsequent prediction for a significant correlation between the *blocking effect* and the *ordinal slope* (Figure 9) and the *growth effect* and the *ordinal slope* (Figure 10). Neither of these correlations was significant: *blocking effect* by *ordinal slope* $r = .14$, $b = 0.07$, and *growth effect* by *ordinal slope* $r = .08$, $b = 0.03$, both p 's $> .44$.²

² I also examined the possibility that the blocked-cyclic *growth effect* from the first three naming cycles may be correlated with the continuous naming *ordinal slope*. For this correlation, I found no outliers. This correlation was not significant, $r = -.11$, $b = -0.08$, $p = .55$.

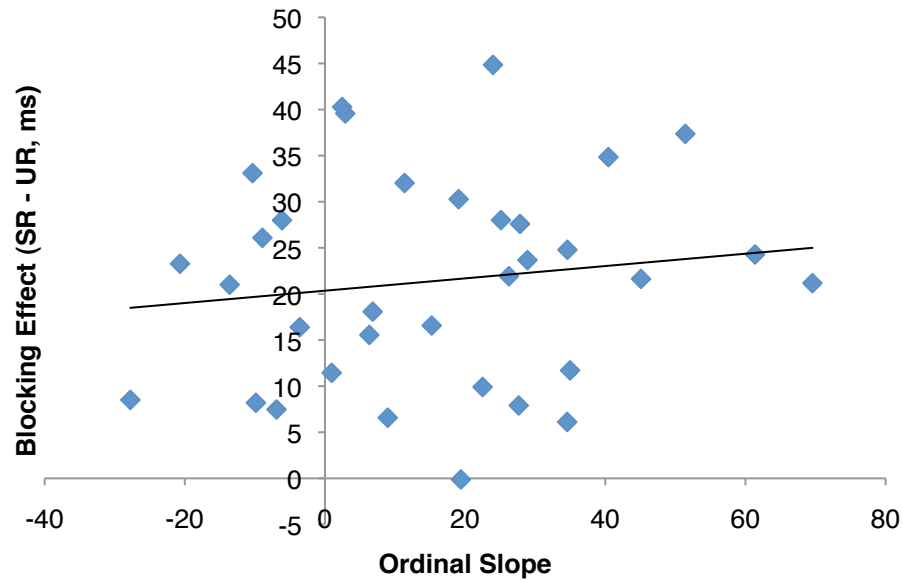


Figure 9. A scatterplot of continuous naming ordinal slope individual effects by blocked-cyclic blocking effect individual effects. (SR, semantically related; UR, unrelated)

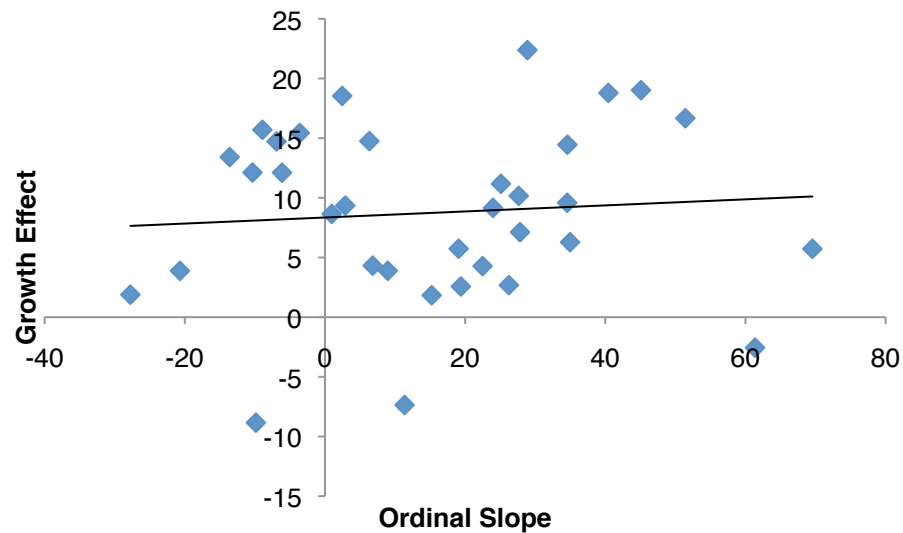


Figure 10. A scatterplot of continuous naming ordinal slope individual effects by blocked-cyclic growth effect individual effects.

I examined the hypothesis that semantic interference in naming is created by *learning* (e.g., Brown & Mitchell, 1988; Oppenheim et al., 2010) and resolved by *boosting* (e.g., Kan & Thompson-Schill, 2004; Oppenheim et al., 2010) by testing the subsequent prediction that individuals' abilities in *learning* (as measured by repetition

priming) and *boosting* (as measured by high/low NA naming) should positively correlate with their degree of semantic interference. Therefore, I tested the relationship between semantic interference measures and those measuring the *learning* and *boosting mechanisms*. To test learning, I correlated the *blocking effect* with the *learning mechanism*, $r = .08$, $b = 0.01$ (Figure 11), the *growth effect* with the *learning mechanism*, $r = .01$, $b = 0.00$ (Figure 12) and the *ordinal slope* with the *learning mechanism*, $r = .18$, $b = 0.06$ (Figure 13). None of these correlations was significant, all p 's $> .32$.³

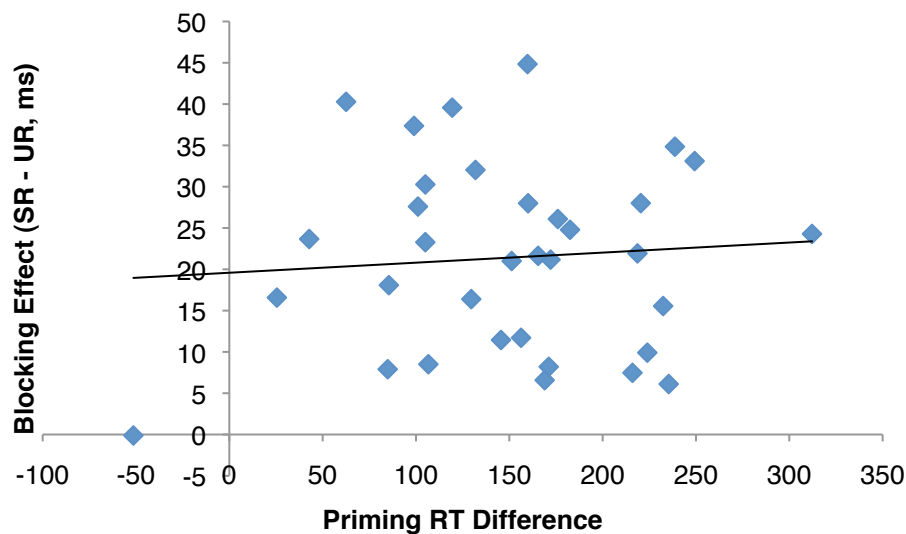


Figure 11. A scatterplot of blocked-cyclic naming blocking effect individual effects by individual repetition priming measurements of the learning mechanism. (SR, semantically related; UR, unrelated)

³ I also examined the possibility that the *learning mechanism* (repetition priming) may be correlated with the magnitude of the difference in RTs between the first and second naming cycles in the unrelated condition. For this correlation, I found no outliers. This correlation was not significant, $r = .05$, $b = 0.09$, $p = .78$.

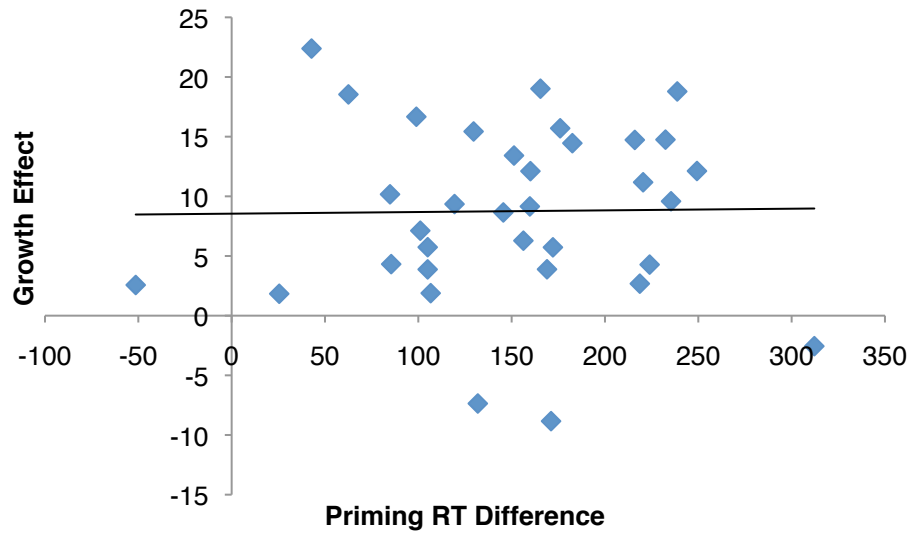


Figure 12. A scatterplot of blocked-cyclic naming growth effect individual effects by individual repetition priming measurements of the learning mechanism.

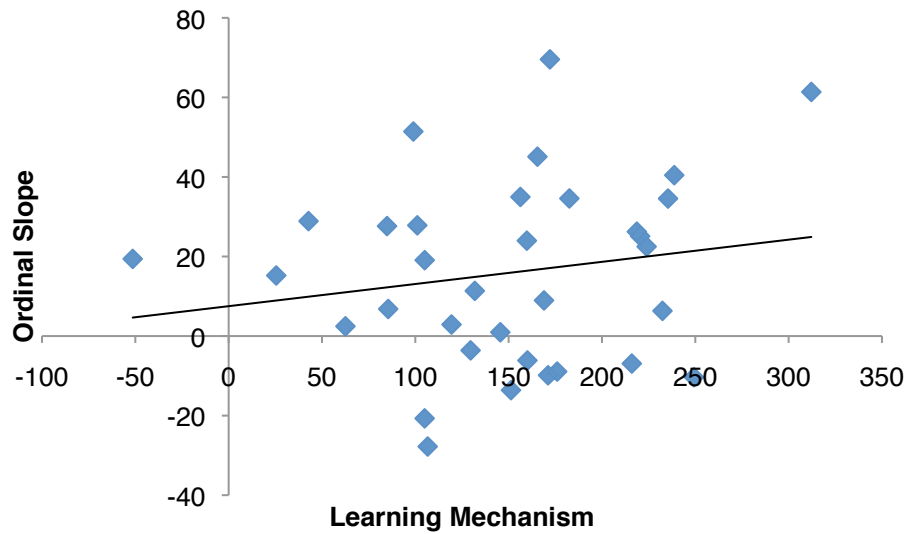


Figure 13. A scatterplot of continuous naming ordinal slope individual effects by individual repetition priming measurements of the learning mechanism.

To test the *boosting mechanism*, I correlated the *blocking effect* with the *boosting mechanism*, $r = .27$, $b = 0.04$ (Figure 14), the *growth effect* with the *boosting mechanism*, $r = .11$, $b = 0.01$ (Figure 15) and the *ordinal slope* with the *boosting mechanism*, $r = .18$, $b = 0.06$ (Figure 16). For the correlation between the *blocking effect* and the *boosting*

mechanism, four outliers were removed from the analysis. None of these correlations was significant, all p 's > .12.

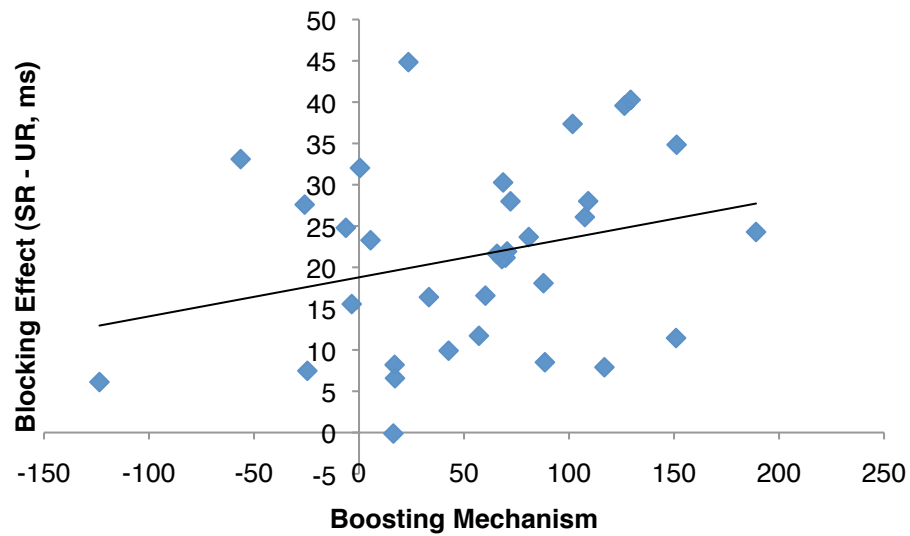


Figure 14. A scatterplot of blocked cyclic naming *blocking effect* individual effects by individual high/low NA measurements of the *boosting mechanism*. (SR, semantically related; UR, unrelated)

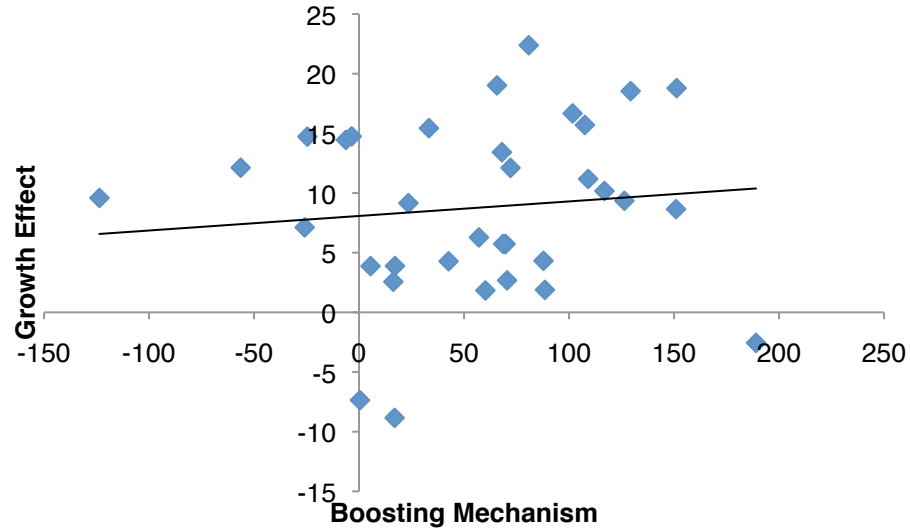


Figure 15. A scatterplot of blocked cyclic naming *growth effect* individual effects by individual high/low NA measurements of the *boosting mechanism*.

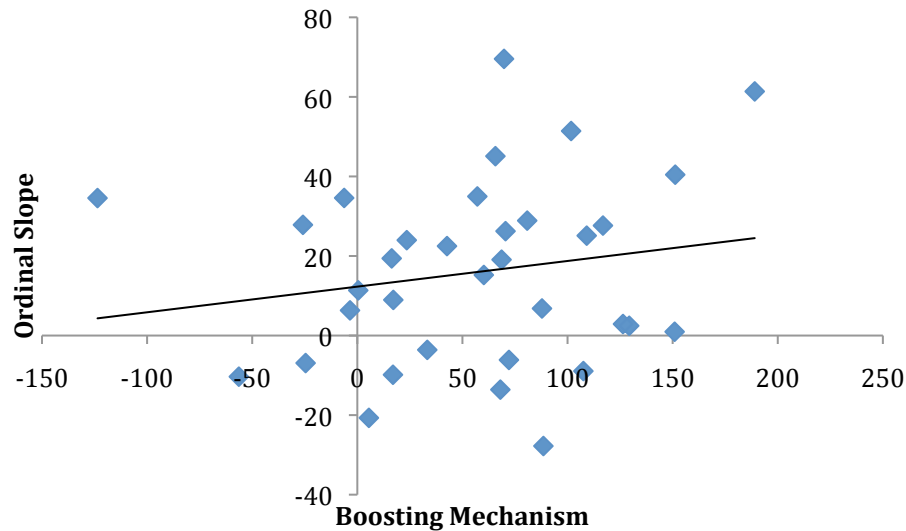


Figure 16. A scatterplot of continuous naming *ordinal slope* individual effects by individual high/low NA measurements of the *boosting mechanism*.

Discussion

In the correlation analyses, I tested predictions from three hypotheses of the Dark Side Model (Oppenheim et al., 2010) which proposes that semantic interference effects in blocked-cyclic and continuous naming tasks are (1) measures of the same effect, (2) created by a *learning mechanism* and (3) resolved by a *boosting mechanism*. To test these predictions, I correlated measures of semantic interference across tasks, and these same semantic interference effects with measures of the *learning* and *boosting mechanisms*. However, no correlation was significant, questioning the ability of this model to accurately account for semantic interference effects in naming. Specifically, the measures of semantic interference in blocked-cyclic naming (*blocking effect*, *growth effect*) and continuous naming (*ordinal slope*) were not correlated, a surprising finding, as they are assumed to be manifestations of the same underlying processes (Oppenheim, et al., 2010). Additionally, the *learning mechanism*, as measured by repetition priming, did not predict semantic interference effects in these tasks despite the claim that the *learning*

mechanism responsible for repetition priming (facilitation) is also the basis of interference. Furthermore, the *boosting mechanism*, as measured by high/low name agreement (NA) in picture naming, did not predict the semantic interference effects in these paradigms, despite the proposed role of this mechanism in resolving competition (e.g., Kan & Thompson-Schill, 2004).

It is worth noting that the lack of significant correlations cannot be accounted for by the presence of outliers either in the individual experiments or in the correlation analyses. Further, using both raw RTs as well as log-transformed data did not change the results. To ensure there was no possibility of committing a *Type II* error, I examined these data with and without correcting for multiple comparisons using various statistical measures that control for intrasubject variability (i.e., *t*-scores), and also verified the internal reliability of each experimental measure (i.e., Spearman-Brown formula). No correlation reached significance in any of these analyses. While previous research has found significant correlations between semantic interference effects across tasks (blocked-cyclic naming and picture-word interference; Shao, Z., Roelofs, A., Martin, R., and Meyer, A. S., in preparation), these tasks were performed using the same stimuli. Here, I specifically avoided using the same items in more than one task, as when items are named, the Dark Side Model (Oppenheim et al., 2010) proposes they are strengthened and semantically related items weakened by the *learning mechanism*, and the lexical-semantic link changes in the first semantic interference task are predicted to impact the interference effects observed in the second. Although I found the typical semantic interference effects in both blocked-cyclic naming (e.g., Belke et al., 2005; Damian & Als, 2005; Damian et al., 2001; Maess et al., 2002; Navarrete et al., 2012; Schnur et al.,

2006) and continuous naming (e.g., Howard et al., 2006; Runnqvist et al., 2012; Navarrete et al., 2010), measures of learning and boosting did not correlate with these effects. This suggests that the nature of semantic interference effects in language production is less well understood than previously thought. However, to confirm that my predictions were consistent with the model architecture, I completed a number of post hoc model simulations investigating the semantic interference effects observed in the blocked-cyclic and continuous naming paradigms as they relate to variability in the *learning* and *boosting mechanisms*. These simulations are presented below.

Model Simulations

Using the Dark Side Model architecture proposed by Oppenheim et al. (2010), I sought support for the predictions outlined in the previous sections. Namely, that semantic interference effects in blocked-cyclic and continuous naming are measures of the same effect, caused by a *learning mechanism* and resolved by a *boosting mechanism*. That semantic interference effects in blocked-cyclic and continuous naming are caused by the same mechanisms implies that large interference effects in one task should be accompanied by larger interference in the other task and vice versa. If semantic interference in these tasks is created by a *learning mechanism*, then the stronger this *learning mechanism*, the greater semantic interference effects will be. Finally, if semantic interference in these tasks is resolved by a *boosting mechanism*, then the stronger this *boosting mechanism*, the smaller semantic interference effects will be.

To test the first prediction of the Dark Side Model (Oppenheim et al., 2010), I simulated the semantic interference effects in blocked-cyclic and continuous naming by changing the model's parameters of *learning* and *boosting* to simulate individual

performance on each of these tasks⁴. For varying levels of *learning* and *boosting*, I calculated the *blocking effect* and *growth effect* in blocked-cyclic naming and the *ordinal slope* in continuous naming (see Figures 17 and 18). Calculating these semantic interference effects across varied levels of *learning* and *boosting* is analogous to examining the semantic interference effects across individuals, in which each combination of the *learning* and *boosting mechanism* parameters can be considered as one individual. Taking these individual performance measures, if the semantic interference effects in these two tasks are correlated across various levels of *learning* and *boosting*, then the model performance indicates that these two paradigms are measuring the same interference effect. As shown in Figures 17 and 18 (in which each point is representative of an individual's semantic interference effects), this prediction is motivated by the model's simulations of these two semantic interference tasks, as the magnitude of interference in blocked-cyclic naming (*blocking effect* and *growth effect*) and the magnitude of interference in continuous naming (*ordinal slope*) are strongly correlated. For the correlation between the *blocking effect* and *ordinal slope*, $r = .95$, $b = 0.16$, $p < .001$, and for the *growth effect* and the *ordinal slope*, $r = .95$, $b = 0.40$, $p < .001$.

⁴ I would like to thank Tao Wei for her assistance with these model simulations.

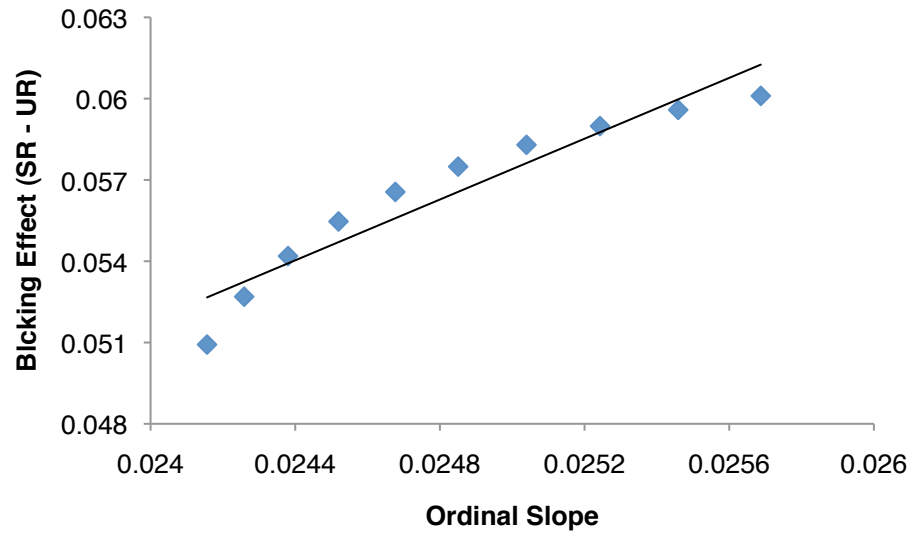


Figure 17. Correlation of model simulated *blocking effect* in blocked-cyclic naming and the *ordinal slope* in continuous naming. The *blocking effect* is calculated as the difference in the log-transformed number of boosts required for items to be selected in the related condition compared to the unrelated condition. The *ordinal slope* is calculated as slope of the increase in the difference of the log-transformed number of boosts required for selection between of items from the same semantic category across ordinal positions. (SR, semantically related; UR, semantically unrelated)

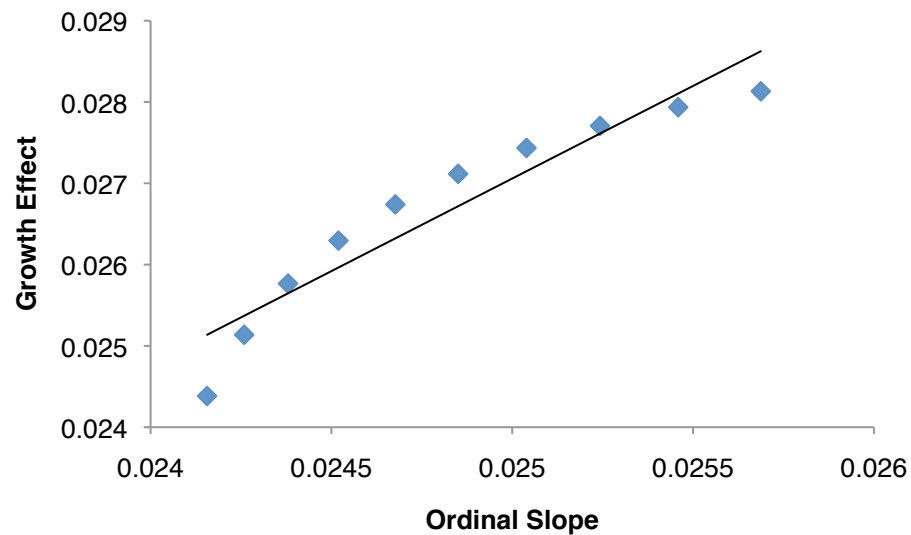


Figure 18. Correlation of the model simulated *growth effect* in blocked-cyclic naming and the *ordinal slope* in continuous naming. The *growth effect* is calculated as the increase in the difference of the log-transformed number of boosts required for selection between the related and unrelated conditions, across cycles. The *ordinal slope* is calculated as slope of the increase in the difference of the log-transformed number of boosts required for selection between of items from the same semantic category across ordinal positions.

I tested the prediction that the Dark Side Model's (Oppenheim et al., 2010) *learning mechanism* creates semantic interference in blocked-cyclic and continuous naming by simulating performance in these tasks across a wide range of *learning* parameters (0.5-0.95) while holding the *boosting mechanism* constant. Original model simulations used a *learning* rate of 0.75 (Oppenheim et al., 2010). These simulations explore the impact that the *learning mechanism* has on semantic interference effects in order to determine if changing the *learning* strength impacts semantic interference effects. As displayed in Figures 19, 20 and 21, increasing the strength of the *learning mechanism* does in fact increase the magnitude of semantic interference as measured by the *blocking effect* ($r = .98$, $b = 0.02$, $p < .001$; Figure 19), the *growth effect* ($r = .98$, $b = 0.01$, $p < .001$; Figure 20) and the *ordinal slope* ($r = .99$, $b = 0.003$, $p < .001$; Figure 21), consistent with the view that the magnitude of the semantic interference effect is mediated by one's *learning mechanism* in both tasks.

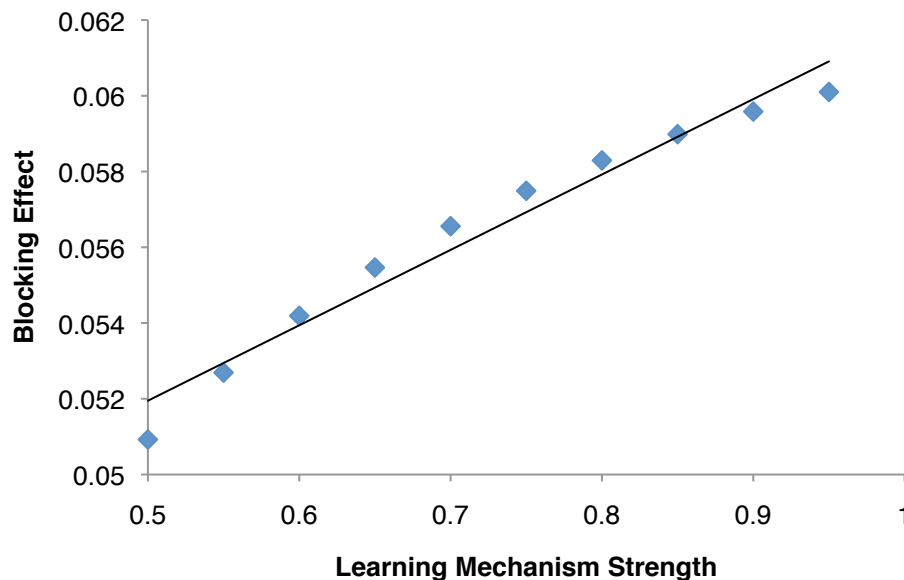


Figure 19. Simulation of the *blocking effect* in blocked-cyclic naming across increasing *learning mechanism* strength. The *blocking effect* is calculated as the difference in the log-transformed number of boosts required for items to be selected in the related condition compared to the unrelated condition.

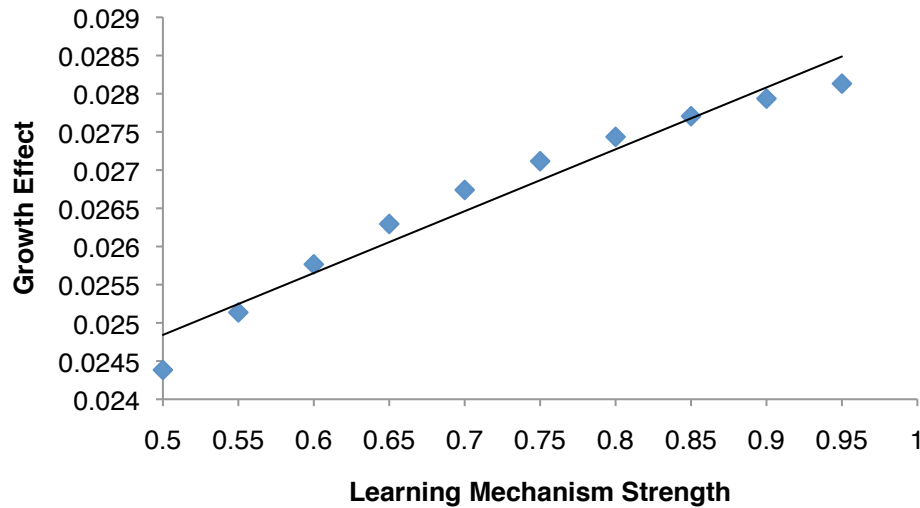


Figure 20. Simulation of the *growth effect* in blocked-cyclic naming across increasing *learning mechanism* strength. The *growth effect* is calculated as the increase in the difference of the log-transformed number of boosts required for selection between the related and unrelated conditions, across cycles.

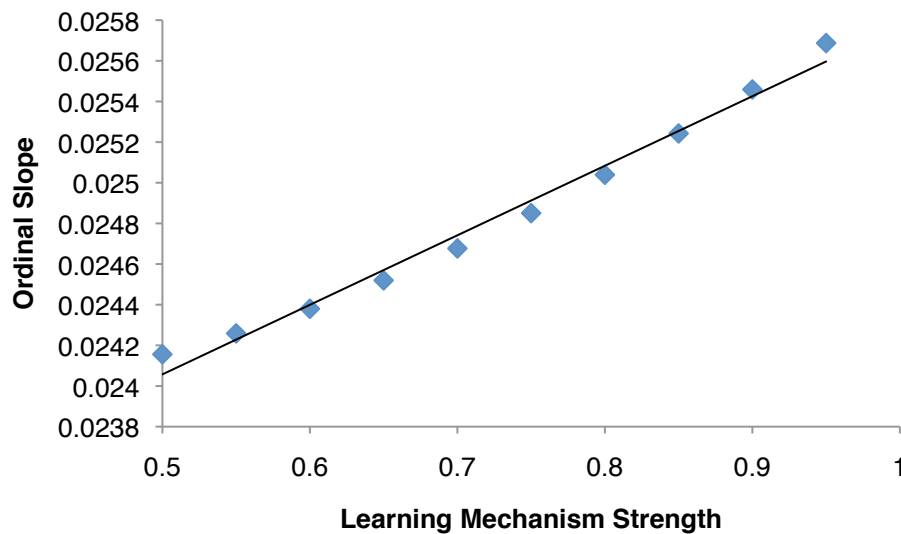


Figure 21. Simulation of the *ordinal slope* in continuous naming across increasing *learning mechanism* strength. The *ordinal slope* is calculated as slope of the increase in the difference of the log-transformed number of boosts required for selection between of items from the same semantic category across ordinal positions.

I tested the prediction that the Dark Side Model's (Oppenheim et al., 2010) *boosting mechanism* resolves semantic interference in blocked-cyclic and continuous naming by simulating performance in these tasks across a range of *boosting* parameters (1.002-1.01) while holding the *learning mechanism* constant. The original model

simulations used a *boosting* rate of 1.01, and I capped simulations at this value, as higher *boosting mechanism* strength facilitates naming to the point where semantic interference effects are no longer present. As displayed in Figures 22, 23 and 24, varying the strength of the *boosting mechanism* did not impact the magnitude of semantic interference as measured by the *blocking effect* ($r = 0$, $b = 0$; Figure 22), the *growth effect* ($r = 0$, $b = 0$; Figure 23) and the *ordinal slope* ($r = 0$, $b = 0$; Figure 24). These simulations are at odds with the predictions about the *boosting mechanism*.

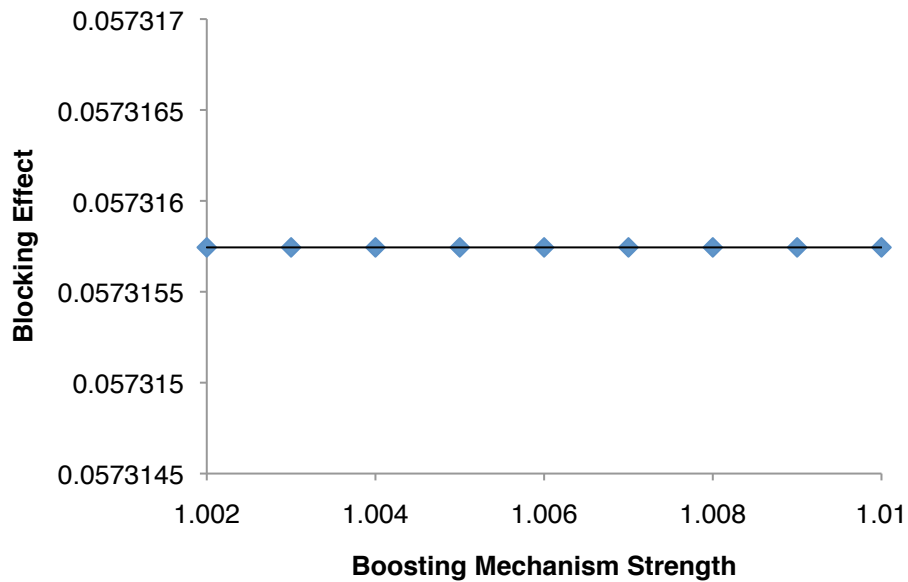


Figure 22. Simulation of the *blocking effect* in blocked-cyclic naming across increasing *boosting mechanism* strength. The *blocking effect* is calculated as the difference in the number of boosts required for items to be selected in the related condition compared to the unrelated condition.

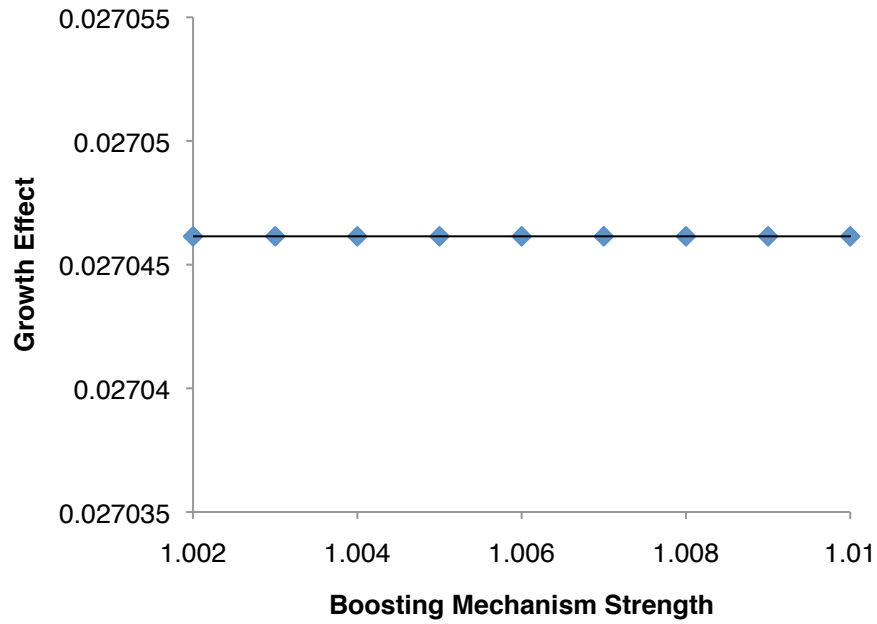


Figure 23. Simulation of the *growth effect* in blocked-cyclic naming across increasing *boosting mechanism* strength. The *growth effect* is calculated as the increase in the difference of the number of boosts required for selection between the related and unrelated conditions, across cycles.

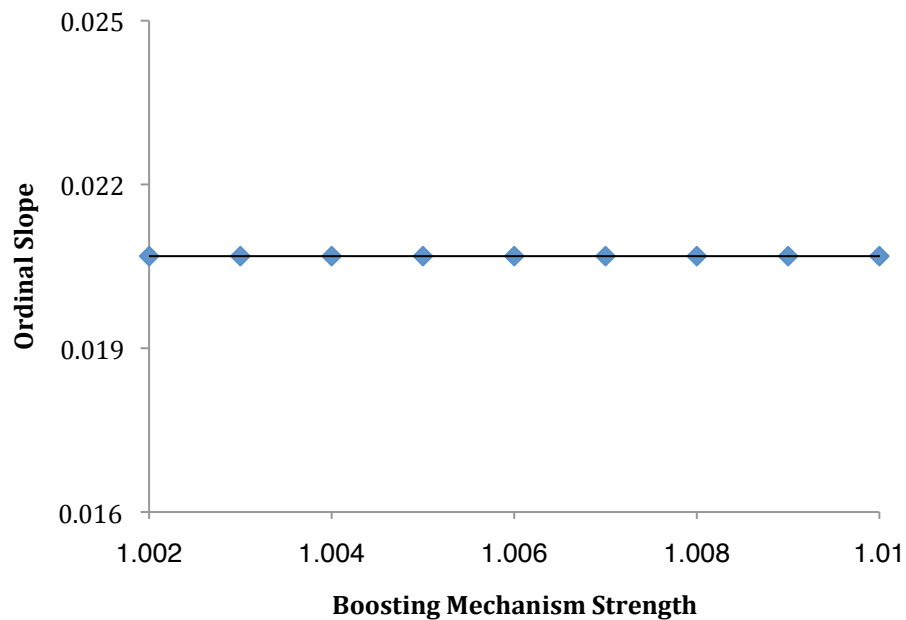


Figure 24. Simulation of the *ordinal slope* in continuous naming across increasing *boosting mechanism* strength. The *ordinal slope* is calculated as the slope of the increase in the difference of the number of log-transformed boosts required for selection between items from the same semantic category across ordinal positions (1-5).

Discussion

In the model simulations, I sought to confirm that the three predictions I generated from the Dark Side Model (Oppenheim et al., 2010) are consistent with its performance. Specifically, I wanted to confirm that the model does indeed propose that semantic interference in blocked-cyclic and continuous naming tasks are (1) measures of the same effect, (2) created by a *learning mechanism* and (3) resolved by a *boosting mechanism*. When I simulated individual performance in the blocked-cyclic and continuous naming paradigms by varying the parameters for *learning* and *boosting*, the magnitude of semantic interference in blocked-cyclic naming correlated with continuous naming. This demonstrates that, at least in this model, semantic interference in blocked-cyclic naming is caused by the same mechanisms as in continuous naming. With regard to the *learning mechanism*, I calculated the three semantic interference effects across increasing *learning mechanism* strength and found that for each effect, greater *learning* strength led to increased semantic interference. This is consistent with the hypothesis that semantic interference in blocked-cyclic and continuous naming is created by the *learning mechanism*. To investigate the *boosting mechanism*, I calculated the semantic interference effects across increasing *boosting mechanism* strength and found that increasing *boosting* strength did not lead to any differences in any of the calculated semantic interference effects. This is in contrast to the hypothesis that semantic interference in blocked-cyclic and continuous naming is resolved by the *boosting mechanism*, which predicts that increasing *boosting mechanism* strength will decrease the magnitude of semantic interference.

To summarize, the findings from the model simulations provide support for the hypotheses that semantic interference effects in blocked-cyclic and continuous naming

are measures of the same effect and created by the *learning mechanism*. In light of these findings, it is surprising that none of the planned correlations that tested these hypotheses using individual RT data provided support for the model's predictions. However, simulations failed to support the assumption that semantic interference in blocked-cyclic and continuous naming is resolved by a *boosting mechanism*. In light of these findings, it may not be surprising that none of the planned correlations testing this final hypothesis was significant. However, that changes in the *boosting mechanism* have no impact on performance is inconsistent with evidence concerning the *boosting mechanism* and its required role in times of increased competition (e.g., Kan & Thompson-Schill, 2004; Oppenheim et al., 2010; Schnur et al., 2006, 2009). Therefore, taking together both the findings from the correlational analyses and the model simulations, these results do not support the assumptions inherent in the Dark Side Model (Oppenheim et al., 2010), suggesting that our understanding of semantic interference effects is incomplete. In the General Discussion, I will discuss possibilities as to why I did not find support for the assumptions of the Dark Side Model (Oppenheim et al., 2010) in either the cross-task semantic interference correlations or the correlation of semantic interference effects with measures of the *learning* and *boosting mechanisms*.

General Discussion

The purpose of this study was to test whether the semantic interference effects observed in blocked-cyclic naming and continuous naming reflect the same processes, and are created and resolved by *learning* and *boosting mechanisms*, respectively. Specifically, I tested the following assumptions of a computational model designed to simulate the behavioral effects of both paradigms (i.e., Dark Side Model; Oppenheim et

al., 2010):

1. The semantic interference effects observed in blocked-cyclic and continuous naming are the same effect.
2. A *learning mechanism* creates semantic interference in blocked-cyclic and continuous naming.
3. A *boosting mechanism* facilitates the resolution of semantic interference in blocked-cyclic and continuous naming.

I tested the same participants in blocked-cyclic and continuous naming to determine whether a relationship exists between the interference effects observed across tasks. I measured individual variability in the overall magnitude of semantic interference in blocked-cyclic naming (i.e., *blocking effect*), the increase of interference across naming cycles in blocked-cyclic naming (i.e., *growth effect*), and the increase in semantic interference when naming across multiple category exemplars in continuous naming (i.e., *ordinal slope*). Participants also performed a repetition priming task and a high/low picture name agreement (NA) task to measure the *learning* and *boosting mechanisms*, respectively. Surprisingly, I found that interference effects across tasks did not correlate, nor did they relate to individual measures of the *learning* and *boosting mechanisms*.

While adjusting the model's parameters provided support for the predictions that semantic interference in blocked-cyclic and continuous naming are measures of the same effect and that this effect is created by connection weight changes (*learning mechanism*), model simulations changing the *boosting mechanism* did not affect the magnitude of semantic interference. Together, these behavioral findings are contrary to computational predictions made by the Dark Side Model (Oppenheim et al., 2010), suggesting that

semantic interference effects in blocked-cyclic and continuous naming are driven by factors outside of the functions of *learning* and *boosting*, at least as they are implemented in this model. The remainder of this discussion will explore potential explanations for why semantic interference in blocked-cyclic and continuous naming differs, why the *learning mechanism* did not predict behavioral semantic interference effects, and why *boosting mechanism* did not relate to semantic interference effects either computationally or behaviorally.

Semantic Interference Effects

Why was there no relationship between individuals' magnitude of semantic interference across two naming tasks (blocked-cyclic and continuous naming)? Both paradigms elicit semantic interference whereby naming multiple items from the same semantic category slows the production process. For this reason, they are considered variations of the same paradigm (i.e., serial naming; Oppenheim et al., 2010), and the Dark Side Model predicts that they measure the same semantic interference effect. However, there are marked differences between these two tasks. One involves repetition as well as obvious semantic groupings (blocked-cyclic naming), while the other merely presents a list of images to be named without any type of repetition or obvious semantic relationships (continuous naming; cf., Navarrete et al., 2012). Additionally, in blocked-cyclic naming, items from the same semantic category are named without any interleaved unrelated items (but see Damian & Als, 2005) which emphasizes semantic relationships, while in continuous naming, semantically related items are separated from each other by at least two unrelated trials (Experiment 2; Runnqvist et al., 2012) or more (i.e., 4, 6, 8; Howard et al., 2006; Navarrete et al., 2010), a manipulation which does not emphasize

semantic relationships. Thus, repetition of items and emphasis on semantic relationships are two major methodological differences between blocked-cyclic and continuous naming, which may account for the lack of correlation between semantic interference effects across paradigms.

In light of the differences between these two paradigms in repetition and semantic relationship emphasis, interference effects in these experiments potentially did not correlate because interference occurs at different parts of the language system depending on the task (e.g., at a semantic level in one paradigm and a lexical level in the other). However, both tasks require subjects to name pictures whereby one must activate the semantic features of a target picture in order to retrieve the correct lexical item (i.e., semantically-driven lexical access; Damian et al., 2001). Thus, the explanation that they are entirely different does not immediately appear viable as both tasks engage the lexical-semantic processes of the language production system in a similar manner. Furthermore, previous research supports the idea that it is this semantically-driven lexical access that causes interference in each task. For example, semantic interference is not elicited when participants semantically categorize items instead of naming them; so semantic interference is not attributed to the semantic level alone (Damian et al., 2001). Likewise, reading written words instead of naming pictures eliminates the semantic interference effect, indicating that simple lexical or phonological access is not sufficient for semantic interference to arise (e.g., Damian et al., 2001; Masson, 1995). Overall, these findings demonstrate that the semantic interference effect is the result of the language system retrieving semantic information in order to access lexical items. As blocked-cyclic and continuous naming appear to share at least the locus of the semantic interference effect

(semantically-driven lexical access), the possibility that these effects occur at different levels in the production system is an unlikely explanation for the lack of correlation between them.

Alternatively, although these tasks share the source of semantic interference, repeating small sets of items in blocked-cyclic naming may recruit executive top-down strategies that cause it to differ from continuous naming, in which these strategies may not be used. Repetition is the most obvious difference between these two tasks, as blocked-cyclic naming involves repetition whereas continuous naming does not. In blocked-cyclic naming, this repetition promotes explicit awareness of semantic categories, and this knowledge may influence performance (for a similar account, see Belke & Stielow, 2013; Abdel Rahman & Melinger, 2010), while in continuous naming any knowledge of semantic categories is more appropriately attributed to implicit awareness of category repetition (Howard et al., 2006). Furthermore, as repetition is combined with small sets of items in blocked-cyclic naming, participants may be able to hold these items in short term memory and use executive top-down strategies outside of the language system to counteract semantic interference in this paradigm by predicting which items will be presented (Belke, 2008). That top-down strategies are potentially used in blocked-cyclic naming but not in continuous naming makes these executive processes a viable candidate for a component that is involved in one semantic interference task but not in the other.

Previous research provides support for a difference in the task demands of blocked-cyclic and continuous naming, suggesting that the former recruits executive processes and the latter does not. Belke (2008) used the blocked-cyclic naming task with

and without a concurrent digit-retention task that relies on working memory resources and found that a working memory load (digit string) increased the magnitude of semantic interference. This finding indicates that taxing working memory resources holds captive executive processes that participants would otherwise use to attenuate the semantic interference effect, thus leading to increased semantic interference. However, while these processes may be at play in blocked-cyclic naming, a recent study reveals no such role for executive strategic processes in continuous naming performance. Following Belke (2008), Belke and Stielow (2013) used the same digit-retention task in the continuous naming paradigm. Contrary to what Belke (2008) found, this study demonstrated that working memory load did not change the magnitude of the semantic interference effect in continuous naming (Belke & Stielow, 2013). Together, these findings provide compelling evidence that executive processes play an important role in the blocked-cyclic naming task, but not in the continuous naming task. Thus, a likely explanation for why semantic interference effects did not correlate between blocked-cyclic and continuous naming is that by virtue of repeating items, the blocked-cyclic naming task promotes the recruitment of executive top-down strategies while continuous naming does not.

Learning Mechanism

That the *learning mechanism* as measured by repetition did not correlate with the magnitude of semantic interference is likely due to differences between these paradigms (as described above), and/or that contrary to the Dark Side Model (Oppenheim et al., 2010), repetition priming does not reflect the *learning* that occurs to create semantic interference. The *learning mechanism* implemented in Oppenheim et al.'s (2010) model reflects processes that create both facilitation and interference in naming through

persistent lexical-semantic connection weight changes that are responsible for both repetition priming and semantic interference effects. Oppenheim et al. (2010) state that these effects are "...two sides of the same coin..." (p. 227), both served by a unitary *learning mechanism* in which a single parameter (the *learning rate*) determines both the weakening and strengthening functions of the *learning* process. However, the *learning mechanism* as measured by repetition priming and the semantic interference effects in blocked-cyclic and continuous naming were not correlated. That blocked-cyclic naming involves additional processes outside of the language production system (e.g., executive processes; Belke, 2008) may account for the current findings with respect to semantic interference in this task. In contrast, measures of *learning* should show a relationship with semantic interference in the continuous naming paradigm since this task does not necessarily involve mechanisms external to the language system (Belke & Stielow, 2013), and more importantly does not confound the *learning mechanism's* strengthening (repetition of items) with weakening. Even so, the *learning mechanism* (measured by repetition priming) and semantic interference in continuous naming (measured by *ordinal slope*) did not correlate. Although Oppenheim et al. (2010) propose that repetition priming reflects the same *learning mechanism* that operates to create semantic interference in naming, the results here and elsewhere suggest that this is not the case.

While some evidence suggests that repetition priming and semantic interference are the result of the same type of process (i.e., *learning*), differences exist in the nature of these effects, which indicate that these two effects (facilitation vs. interference) may occur at different levels of the language system. For example, both semantic interference (e.g., Damian & Als, 2005; Howard et al., 2006; Schnur et al., 2009) and repetition

priming (Durso & Johnson, 1979; Cave, 1997) are temporally persistent, lending support to the idea that *learning* occurs in each task, causing changes to aspects of the language system which then impact future production. However, the time course of semantic interference differs from repetition priming, as semantic interference occurs with up to eight items between category members, but dissipates when many more unrelated pictures are named between related items (Schnur, Submitted; Wheeldon & Monsell, 1994). Repetition priming, however, not only lasts with up to 50 intervening items between repetitions (Durso & Johnson, 1979) but also with up to 48 weeks between repetitions (Cave, 1997). Furthermore, although Oppenheim et al. (2010) modeled both repetition priming and semantic interference effects at the same level (lexical-semantic links), other studies investigating repetition priming attribute this effect as arising from strengthened connections between lexical and phonological levels (lexical-phonological links) (e.g., Damian & Als, 2005). Indeed, when Damian and Als (2005) proposed that semantic interference effects result from *learning* processes similar to those in repetition priming (see also Vitkovich & Humphreys, 1991), they pointed out that “this solution has the benefit that the same principle...proposed to account for repetition priming...can account for semantic context effects as well, just at a different locus” (p. 1382). Overall, while *learning* processes are important factors in speech production, the results from this study suggest that repetition priming and semantic interference do not involve the same *learning* process.

Boosting Mechanism

The *boosting mechanism* implemented in Oppenheim et al.’s (2010) model operates to select a lexical item for production. During the naming process, this

mechanism enhances the activation of all activated lexical items until the target can be discerned from the others as “...when more than one word is activated, it is assumed to be difficult to identify the most active one...” (Oppenheim et al., p. 231). This explanation of the *boosting mechanism* is consistent with findings that an executive selection mechanism (“booster”) is critical to resolving interference in the midst of heightened competition (e.g., Kan & Thompson-Schill, 2004; Thompson-Schill et al., 1998) and is called upon to aid performance in semantic interference tasks (Pisoni et al., 2012; Schnur et al., 2009). However, as described in the results, model simulations exploring the effects of the *boosting mechanism* on the magnitude of semantic interference in blocked-cyclic and continuous naming did not find support for the assumption that the *boosting mechanism* is critical to resolving semantic interference, and using high/low name agreement as a measure of *boosting* (Kan & Thompson-Schill, 2004) did not predict the magnitude of semantic interference across these two paradigms. This is inconsistent both with findings that the *booster* is critical during blocked-cyclic naming performance (Pisoni et al., 2012; Schnur et al., 2009) and current theories of the *booster* as a resource that comes “on-line” to assist when selection is tough by aiding to resolve competition (e.g., Thompson-Schill et al., 1998). Instead of being called upon when selection is especially difficult, such as when naming an item semantically related to a previously produced item, the *boosting mechanism* as implemented by the Dark Side Model (Oppenheim et al., 2010) is constantly operating throughout the model’s simulations. In fact, it is by incorporating the *boosting* process that Oppenheim et al. (2010) are able to simulate behavioral response time data, by counting and log-transforming the number of boosts required for any item to be selected and interpreting

these values as analogous to response latencies in behavioral performance. Therefore, the Dark Side Model's *boosting mechanism* does not resolve interference during selection as much as it operates as an overall selection mechanism, used to select any and all items for production, regardless of the amount of competition present in the system. In sum, while previous research supports a mechanism critical to resolving semantic interference (e.g., Pisoni et al., 2012; Schnur et al., 2009), this mechanism is not modeled by the *boosting mechanism* proposed in the Dark Side Model (Oppenheim et al., 2010), explaining both why simulations varying *boosting* strength did not correlate with magnitude of semantic interference, and why individual measures of *boosting* did not correlate with semantic interference effects.

Adapting the Dark Side Model

Oppenheim et al. (2010) propose the Dark Side Model as a computational account for the semantic interference effects in blocked-cyclic and continuous naming tasks. Their model uses *learning* and *boosting mechanisms* to successfully replicate data from several different studies testing semantic interference in both normal and aphasic speakers. However, model predictions did not find support in the correlational analyses of healthy speakers' naming data that tested the relationship between semantic interference effects in blocked-cyclic and continuous naming and their basis in *learning* and *boosting mechanisms*.

Taking the Dark Side Model's (Oppenheim et al., 2010) current architecture as a starting point, the current data suggest three modifications that potentially may increase the model's ability to simulate semantic interference effects. First, by adding a phonological level, we can model repetition priming as a change in the links between

lexical and phonological representations (following Damian & Als, 2005; Wheeldon & Monsell, 1992). In blocked-cyclic naming this will still provide a repetition priming effect across naming cycles, however, the main processes in repetition priming (lexical-phonological changes) will be dissociated from those which weaken lexical-semantic links and create semantic interference. Even so, the question remains as to the degree to which *learning* changes lexical-semantic links to cause interference and how long this interference persists. Semantic interference does not persist with large numbers of intervening trials (e.g., Schnur, submitted; Wheeldon & Monsell, 1994), so this interference effect is vulnerable to decay. Future research should investigate both the magnitude of lexical-semantic link changes and the time-course of semantic interference using a semantic priming paradigm such as Wheeldon and Monsell (1994) used in which participants name to definition (e.g., “The largest creature that swims in the sea” (p. 337)) and then name a semantically related picture some number of items later (e.g., “shark”). By systematically manipulating the number of intervening trials between related items (i.e., lag) in such a task, future research can determine the magnitude of semantic interference effects independently of repetition of items or categories and also the time-course along which semantic interference persists and then begins to dissipate. Understanding how *learning* changes the language production system to create interference in blocked-cyclic and continuous naming as well as incorporating a phonological level to capture *learning-based* repetition effects, will better equip the Dark Side Model (Oppenheim et al., 2010) to simulate semantic interference.

Second, Belke’s (2008) finding that executive top-down biasing processes such as those in working memory tasks are integral to semantic interference in blocked-cyclic

naming indicates that the model should be modified to include such processes in order to better model semantic interference effects in blocked-cyclic naming (see Roelofs, 2003 for an example of a model with top-down processing). However, it is currently unclear whether these executive strategic processes are recruited due to participants' explicit awareness of repeating semantic categories or due to the repetition of small number of items, and these two accounts generate testable predictions. If executive processes are recruited due to explicit recognition of semantic category, then these processes should also be recruited in the continuous naming task if category names are presented after items are named. In this case, category-explicit continuous naming performance should change due to the presence of a concurrent task that relies on executive processes (e.g., digit-retention; Belke, 2008; Belke & Stielow, 2013) such that interference would be greater with this task than without (as in Belke, 2008). However, if executive strategies are the result of the repetition of small sets of items, then a semantic blocked task (e.g., Kroll & Stewart) with no cyclic component (no repetition) should not recruit these processes, and a concurrent executive task (e.g., digit-retention) would not affect semantic interference (as in Belke & Stielow, 2013). Experiments such as these will not only provide evidence as to how executive processes outside of the language system should be incorporated into the Dark Side Model (Oppenheim et al., 2010), but also how top-down strategy causes the semantic interference effects in blocked-cyclic and continuous naming to differ.

Finally, as the Dark Side Model's *boosting mechanism* as currently instantiated functions as a selection mechanism rather than a booster (e.g., Thompson-Schill et al., 1998), the incorporation of an additional mechanism that assists lexical selection in times

of increased competition will better capture the current understanding of the responsibilities of the *booster* (e.g., as instantiated in Botvinick, Braver, Barch, Carter, & Cohen, 2001). This mechanism should function when naming is particularly prone to interference, such as in the final cycles of the blocked-cyclic naming task or when naming later category members in continuous naming. However, as previous research has generally focused on the role of a lexical selection aide in blocked-cyclic naming (e.g., Pisoni et al., 2012; Schnur et al., 2006; 2009), it is currently unclear if this mechanism is recruited as a result of the explicit awareness of increased competition that stems from knowledge of repeating category members, or simply due to the fact that there is competition in the system, regardless of conscious awareness. Findings support the left inferior frontal gyrus (LIFG) as the neuroanatomical location of this selection aid (e.g., Thompson-Schill et al., 1998), and the ability of this region to resolve competition in blocked-cyclic naming is directly related to the amount of semantic interference (Pisoni et al., 2012; Schnur et al., 2009). Therefore, to investigate the potential of this selection aid to operate independently of conscious awareness of competition, a future direction is to examine semantic interference during continuous naming both when the LIFG has been damaged (as in Schnur et al., 2009) and when LIFG activation is enhanced (e.g., using transcranial direct current stimulation, as in Pisoni et al., 2012). If activation in the LIFG relates to semantic interference in continuous naming, then this selection aid is recruited purely due to competition and not to our conscious awareness of it, and is therefore integral to performance in both blocked-cyclic and continuous naming. Otherwise, this selection aid may be recruited only in blocked-cyclic naming. Gaining insight into the role of a selection aid in blocked-cyclic and continuous naming and

incorporating such an aid into the Dark Side Model (Oppenheim et al., 2010) as a “true” *booster mechanism* will allow us to examine processes necessary to resolve interference during selection independently from lexical selection both in blocked-cyclic and continuous naming.

Thus, the results presented here suggest three modifications to the Dark Side Model to better reflect semantic interference in blocked-cyclic and continuous naming: facilitative *learning* in the links between lexical and phonological representations; an executive top-down biasing process which only comes on-line during blocked-cyclic naming; and a booster mechanism which helps lexical selection only when competition is high. A future research direction is to examine whether the proposed modifications will better capture what causes semantic interference in naming.

Conclusion

This study tested the assumptions of the Dark Side Model (Oppenheim et al., 2010) to determine whether semantic interference effects in blocked-cyclic and continuous naming reflect interference processes driven by a *learning mechanism* and resolved by a *boosting mechanism*. Using a novel approach, this study examined individual differences in not only susceptibility to semantic interference effects across these two tasks but also variability in performance on tasks measuring the mechanisms thought to create and resolve interference (*learning* and *boosting*). Together, the results do not provide support for the *learning* and *boosting mechanisms* implemented in the Dark Side Model. I proposed three ways in which the architecture of the Dark Side Model might be adapted in order to better explain behavioral performance in semantic interference tasks. These changes include adding a phonological level, top-down biasing

capabilities, and an executive selection aid as described in other studies (e.g., Thompson-Schill et al., 1998). Incorporating these three components to the model will address inconsistencies between the current behavioral findings and previous computational simulations, which in turn will provide a better account of processes both intrinsic and external to the language production system. Future research should explore the *learning mechanism* as it may differ in its ability to strengthen and weaken connections and the changes it engenders may be vulnerable to decay at different rates. Future studies should also implement computationally a *boosting* mechanism that encompasses the individual differences in executive selection processes.

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Appendix A

Experiment 1 Stimuli

Acceptable alternatives are listed in parentheses.

Fruit: apple, grapes, banana, orange, pear

Tools: paintbrush, pliers, saw, screwdriver, level

Zoo Animals: elephant, giraffe, hippo, lion, zebra

Farm Animals: pig, goat, rabbit (bunny), sheep, horse

Insects: ant, bee, ladybug, dragonfly, spider

Vegetables: broccoli, carrot, tomato, celery, potato

Accessories: earrings, watch, sunglasses, necklace, tie

School Supplies: chalk, envelope, stapler, eraser, pencil

Musical Instruments: violin, tambourine, piano, guitar, trumpet

Kitchen Items: rolling pin, cup, spoon, plate, toaster

Electronics: battery, CD, keyboard, calculator, printer

Furniture: bed, chair, desk, table, stool

Appendix B
Experiment 2 Stimuli

Acceptable alternatives are listed in parentheses.

Birds: duck, eagle, owl, parrot, swan (goose)

Transportation: bus (schoolbus), car, helicopter, plane (airplane), van

Body Parts: ear, eye, foot, hand, nose

Appliances: dishwasher, fridge (refrigerator), microwave, oven, dryer

Buildings: castle, church, lighthouse, windmill, barn

Fish: eel, shark, stingray, swordfish, goldfish

Headgear: beret, sombrero, crown, cap (hat), hardhat (helmet)

Clothing: bra, jacket (coat), pajamas, skirt, sock

Reptiles and Amphibians: crocodile (alligator), frog (toad), lizard, snake, turtle

Landscape Features: beach, field, mountain, waterfall, desert

House Parts: chimney, door, fireplace, roof, window

Celestial Phenomena: clouds, comet (meteor), lightning, moon, rainbow

Appendix C
Experiment 3 Session 2 Stimuli

Acceptable alternatives are listed in parentheses.

New Items: binder, bow (ribbon), bowl, brain, cane, cooler, cracker, daffodil (flower), drill, elbow, headphones, kayak (canoe), knife, ladder, lamp, monitor (TV), perfume (cologne), pitcher, plant, radio, rattle, razor, shirt (jacket, coat), snail, starfish, thimble, tripod, whisk (mixer)

Old Items: bandage (gauze), accordion, box, bracelet, butterfly, cigarette, comb, corkscrew, cow, drum, fan, gum, gun, house, jar, mirror, overalls, pasta (noodles), pen, pizza, rug, soap, speaker, syringe (needle), tape, telephone (phone), thread (string), tractor, vacuum, wheel

Appendix D
Experiment 4 Stimuli

Acceptable alternatives are listed in parentheses.

High Name Agreement: belt, brick (block), broom, candle, chain, chalk, cherries, clock, dice, feather, fork, hammer, key, leaf, lemon, lipstick, match (matchstick), mushroom, onion, pear, ring, ruler, scarf, screw, staples, toothbrush

Low Name Agreement: almonds (nut), axe (hatchet), boot, cabbage (lettuce), cheese (brie), coins (money, change), cookie, crayon, doll (baby, baby doll), flashlight, glasses (eyeglasses), hat, lime, lock (padlock), marker, mitten (glove), nail, pants, pickle, pill, plunger, ribbon (string), rock (stone), rope, toast (bread), toothpick, vase